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AMERICAN SOCIETY
FOR
TESTING MATERIALS

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A.S.T.M. STANDARDS

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The American Society for Testing Materials had its inception in the organization at Philadelphia, Pa., on June 16, 1898, of the American members of the International Association for Testing Materials under the name of the "American Section of the International Association for Testing Materials."

In 1902, the American Section was incorporated under the name of the "American Society for Testing Materials." Membership in the International Association was required for membership in the Society, and the Society also held membership as a body in the International Association. In 1905, at the Eighth Annual Meeting, the by-laws were amended with a view of leaving membership in the International Association to the individual option of the members of the Society.

Purpose of the Society.

The purpose of the Society, as briefly set forth in its Charter, is "the promotion of knowledge of the materials of engineering and the standardization of specifications and the methods of testing." Through the studies and investigations of its committees, and the presentation of technical papers by its members, the Society contributes largely towards the progress in the field of materials.

The adoption of "Standards," including specifications, methods and definitions, and of "Recommended Practice," has become one of the most important functions of the Society. In general, proposed new Standards or proposed revisions in existing Standards are published for one or more years as Tentative Standards before taking action towards their final adoption.

Membership.

The membership of the Society consists of Honorary Members, Members and Junior Members.

Honorary Members are chosen from among those of widely recognized eminence in some part of the field which the Society aims to cover.

A Member shall be a person not less than twenty-seven years of age, or a corporation, firm, technical or scientific society, teaching faculty or library.

A Junior Member shall be a person less than twenty-seven years of age on the date of his admission, and his status shall be changed to Member at the beginning of the fiscal year next succeeding the date on which he attains the age of twenty-seven years. A Junior Member has the same rights and privileges as a Member, except that he is not eligible for office in the Society.

All applications for membership shall be made on forms which can be obtained from the Secretary-Treasurer. For convenient use, two application blanks for membership are bound in the back of this volume. Applications for membership shall bear the endorsement of two members of the Society.

Annual Dues.

The annual dues are $15 for Members and $7.50 for Junior Members, payable in advance on January 1, the beginning of the fiscal year of the Society. Any member elected after six months of the fiscal year shall have expired may pay only one-half of the dues for that year; but in that case he shall not be entitled to a copy of the Proceedings for the current year. There are no entrance fees.

Number of Members.

The growth in membership has been steady, and reflects the ever increasing activity of the Society in the field of materials. From a membership of 70 in 1898, when the American Section of the International Association was organized, the Society has grown to 3002 (the membership on September 1, 1921), from all parts of the United States, as well as Canada, South America and other foreign countries.

Headquarters.

The headquarters of the Society are in the building of the Engineers' Club of Philadelphia, 1315 Spruce Street, on the third floor. They are centrally located, and convenient to the principal hotels and railway stations. The Engineers' Club is affiliated with the Philadelphia Sections of many of the national engineering and technical societies, and is the center of engineering activity in the Philadelphia district. An auditorium on the second floor of the building, with a seating capacity of 125, and a committee room in the Society headquarters, offer very satisfactory facilities for meetings.

Meetings.

The Society meets annually at a time (usually the last week in June) and place fixed by the Executive Committee. Special meetings may be called in accordance with the provisions of the By-laws.

Executive Committee.

The Society is governed by an Executive Committee consisting of the last three Past-Presidents, and the following twelve officers:

President, two Vice-Presidents, Secretary-Treasurer, and eight Members of Executive Committee.

Standing Committees.

The work of the Society in the standardization of specifications for materials and the methods of testing is accomplished through its standing committees, of which there are now forty with a total membership of 1300. These committees are organized and conduct their work under the Regulations Governing Standing Committees, which appear on pages 859–868. On committees concerned with subjects involving commercial interests, the policy is to maintain an equal numeric balance between the representatives of producing and non-producing interests, although the latter may predominate numerically with the consent of the former. These committees have rendered important service in the formulation of standards, and in promoting knowledge in general of the materials of engineering.

Publications.

The regular publications of the Society, which are issued to the entire membership without charge, are the Proceedings, the Book of A.S.T.M. Standards, the Year Book, and the A.S.T.M. Bulletin.

The Proceedings are issued annually in December and contain the committee reports, with discussions, the new and revised tentative standards accepted at the annual meeting, and the technical papers and discussions presented at the meeting. The Proceedings comprise from 1100 to 1500 pages each year.

The Book of A.S.T.M. Standards, which is published triennially, contains the standards adopted by the Society, including standard specifications, methods and definitions, and recommended practice. The present edition (1921) is the second one issued under the plan of triennial publication, and contains 160 standards.

Standards adopted in the years between the publication of the Book of A.S.T.M. Standards are published in supplementary pamphlet form, of which each member receives a copy.

The Year Book is published annually in September and contains the list of members, personnel of standing committees, the list of standards and tentative standards, and general information concerning the Society.

The A.S.T.M. Bulletin is published quarterly and is supplemented by Circulars to Members issued at irregular intervals throughout the year.

The tentative standards effective during each year are published in a separate volume under the title BOOK OF A.S.T.M. TENTATIVE STANDARDS for the convenience of those who desire to have all tentative standards grouped in one volume and to use them in that form. The 1921 edition of this publication (about 500 pages) contains 127 tentative specifications, methods and definitions.

Each of the standards and tentative standards of the Society are also available in separate pamphlet form.

The Society has also issued the following special publications: (1) an Index of Volumes I to XII of the Proceedings; (2) the Reports from 1903 to 1914 of Committee D-1 on Preservative Coatings for Structural Materials; and (3) a Memorial Volume commemorative of Charles B. Dudley, late President of the Society, which is now out of print.

Non-members may subscribe to the publications of the Society at prices indicated in the accompanying price list. Members may obtain extra copies of the publications, including back numbers of the Proceedings, at special prices indicated in that list.

Joint Activities With Other National Societies.

The Society has joined with other national bodies in a number of cooperative movements, which have usually taken the form of joint committees or councils. The more important of these upon which the Society is now represented are: American Engineering Standards Committee, Engineering Division of the National Research Council, American Bureau of Welding, Joint Committee on Investigation of Phosphorus and Sulfur in Steel, Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, Joint Committee on Concrete Culvert Pipe, Conference Committee with A.S.M.E. Boiler Code Committee, Joint Committee on Standard Pattern Practice.

The wide national significance of the first two in this list justify further brief statements.

American Engineering Standards Committee.—The functions of the American Engineering Standards Committee are: to unify methods of arriving at engineering standards; to secure cooperation between various interested organizations in order to prevent duplication of work and promulgation of conflicting standards, but not itself to formulate standards; to act as an authoritative channel of cooperation in international engineering standardization; to promote in foreign countries a knowledge of American engineering standards; to collect and classify data on standards; and to act as a bureau of information regarding standardization.

The Standards Committee was organized in 1918 by five national technical societies and three government departments engaged in the promulgation of engineering standards. Much time and effort was necessarily spent in the beginning in laying a basis for the Committee's work which has now been going on actively for over a year. The work of the Committee is carried on under a Constitution, Rules of Procedure and By-laws. At this date (September, 1921) 12 American Standards and Tentative American Standards have been approved by the Committee, including nine A.S.T.M. Standards. The Committee has many standardization projects under way. The preparation of Safety Codes in a wide variety of industries is an important feature of the Committee's activities.

The Standards Committee makes it possible to give an international status to approved American Engineering Standards and to cooperate with similar organizations in other countries.

Eighteen national societies and government departments are now represented on the Committee. The headquarters of the Committee are in the Engineering Societies Building, New York City.

Engineering Division, National Research Council.—The National Research Council is an organization of scientists, engineers and educators formed in 1916 in anticipation of the entry of the United States into the World War. The Council was extremely helpful to the Government in the prosecution of the War, and by executive order in 1918 it was permanently established in its useful work. With the cooperation of the Engineering Foundation and the National Engineering Societies, National Research Council early formed an engineering committee which has developed into the Engineering Division of the Council with the following objects: "To carry out the general purpose of coordinating the scientific resources of the entire country as regards engineering and to secure the cooperation of all engineering agencies in which research facilities are available." The organization of the National Research Council has recently been modified to fit peace conditions.

The headquarters of the Engineering Division of the Council are in the Engineering Societies Building, New York City.

International Association for Testing Materials.

The Society has throughout its existence maintained affiliated relations with the International Association for Testing Materials, both through its membership as a body, and through the individual membership on the part of many of its members. The activities of the International Association have been suspended since the beginning of the War in 1914.

A.S.T.M. STANDARDS

CONSISTING OF

STANDARD SPECIFICATIONS,
STANDARD METHODS, STANDARD
DEFINITIONS, RECOMMENDED
PRACTICE

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL RAILS.

Serial Designation: A 1 – 14.

These specifications are issued under the fixed designation A 1; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1907, 1908, 1909, 1914.

I. MANUFACTURE.

Process. 1. The steel shall be made by the Bessemer or open-hearth process as specified by the purchaser. The entire process of manufacture shall be in accordance with the best current practice.

Bled Ingots. 2. Bled ingots shall not be used.

Discard. 3. There shall be sheared from the end of the bloom, formed from the top of the ingot, sufficient metal to secure sound rails.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. The steel shall conform to the following requirements as to chemical composition:

Elements Considered.	Weights, lb. per yd.			
	50 – 69 inclusive.	70 – 84 inclusive.	85 – 100 inclusive.	101 – 120 inclusive.
BESSEMER STEEL.				
Carbon, per cent	0.37 – 0.47	0.40 – 0.50	0.45 – 0.55	0.45 – 0.55
Manganese, per cent	0.80 – 1.10	0.80 – 1.10	0.80 – 1.10	0.80 – 1.10
Phosphorus, max., per cent	0.10	0.10	0.10	0.10
Silicon, max., per cent	0.20	0.20	0.20	0.20
OPEN-HEARTH STEEL.				
Carbon, per cent	0.50 – 0.63	0.53 – 0.66	0.62 – 0.75	0.62 – 0.75
Manganese, per cent	0.60 – 0.90	0.60 – 0.90	0.60 – 0.90	0.60 – 0.90
Phosphorus, max., per cent	0.04	0.04	0.04	0.04
Silicon, max., per cent	0.20	0.20	0.20	0.20

Average Carbon. 5. It is desired that the percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits specified.

Ladle Analyses. 6. (*a*) To determine whether the material conforms to the requirements specified in Section 4, analyses made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt, shall be made as follows:

(*b*) For the Bessemer process an analysis shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulfur and silicon. The carbon content shall be reported for each melt and two averages of the percentages of carbon, manganese, phosphorus, sulfur and silicon shall be reported to the inspector daily, one for each day and night turn respectively.

(*c*) For the open-hearth process an analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulfur and silicon. The chemical composition thus determined shall be reported to the inspector.

Check Analyses. 7. An analysis may be made by the purchaser from a portion of the test ingot furnished by the manufacturer on request of the inspector.

III. PHYSICAL PROPERTIES AND TESTS.

Physical Qualities. 8. Tests shall be made to determine ductility or toughness as opposed to brittleness.

Method of Testing. 9. The physical qualities shall be determined by the drop test.

Drop-Testing Machine. 10. (*a*) The drop-testing machine shall be the standard of the American Railway Engineering Association.

(*b*) The tup shall weigh 2000 lb., and have a striking face with a radius of 5 in.

(*c*) The anvil block shall weigh 20,000 lb., and be supported on springs.

(*d*) The supports for the test pieces shall be a part of or firmly secured to, the anvil. These supports shall be spaced 3 ft. between centers for rails 100 lb. per yd. or less in weight and 4 ft. for rails over 100 lb. per yd. in weight. The bearing surfaces of the supports shall have a radius of 5 in.

Test Piece. 11. (*a*) Drop tests shall be made on pieces of rail not less than 4 ft. and not more than 6 ft. long. These test pieces shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks 1 in. apart for 3 in. each side of the center of the test piece, for measuring the ductility of the metal.

(*b*) The temperature of the test piece when tested shall be between 60 and 100° F.

Height of Drop. 12. The test piece shall ordinarily be placed head upwards on the supports, and be subjected to impact of the tup falling free from the following heights:

WEIGHT OF RAIL, LB. PER YD.		HEIGHT OF DROP, FT.
50 – 60	inclusive	15
61 – 79	"	16
80 – 90	"	17
91 – 100	"	18
101 – 120	"	21

Elongation or Ductility.

13. (*a*) Under impacts, the rail under one or more blows shall show at least 6 per cent elongation for one inch or 5 per cent each for two consecutive inches of the 6-in. scale, marked as described in Section 11.

(*b*) A sufficient number of blows shall be given to determine the complete elongation of the test piece of at least every fifth melt of Bessemer steel, and of one out of every three test pieces of a melt of open-hearth steel.

Permanent Set.

14. It is desired that the permanent set after one blow under the drop test, as measured by the middle ordinate in a length of 3 ft., shall not exceed that in the following table, and a record shall be made of the information:

Section.	Weight, lb. per yd.	Moment of Inertia.	Permanent Set, in.	
			Bessemer Process.	Open-Hearth Process
A.R.A. – A	100	48.94	1.65	1.45
A.R.A. – B	100	41.30	2.05	1.80
A.R.A. – A	90	38.70	1.90	1.65
A.R.A. – B	90	32.30	2.20	2.00
A.R.A. – A	80	28.80	2.85	2.45
A.R.A. – B	80	25.00	3.15	2.85
A.R.A. – A	70	21.05	3.50	3.10
A.R.A. – B	70	18.60	3.85	3.50

Drop Test Requirements, Bessemer Process.

15. (*a*) One piece shall be tested from each melt of Bessemer steel.

(*b*) If the test piece does not break at the first blow and shows the required elongation (Section 13), all the rails of the melt shall be accepted.

(*c*) If the test piece breaks at the first blow or does not show the required elongation (Section 13), all of the top rails of the melt shall be rejected.

(*d*) A second test shall then be made of a test piece selected by the inspector from the top end of any second rail or the bottom end of any top rail of the same melt, preferably of the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 13), all the remaining rails of the melt shall be accepted.

(*e*) If the second test piece breaks at the first blow or does not show the required elongation (Section 13), all the second rails of the melt shall be rejected.

(*f*) A third test shall then be made of a test piece selected by the inspector from the top end of any third rail or the bottom end of any second rail of the same melt, preferably of the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 13), all the remaining rails of the melt shall be accepted.

(*g*) If the third test piece breaks at the first blow or does not show the required elongation (Section 13), all the remaining rails of the melt shall be rejected.

Drop Test Requirements, Open-Hearth Process.

16. (*a*) Test pieces shall be selected from the second, middle and last full ingot of each open-hearth melt.

(*b*) If two of these tests pieces do not break at the first blow and both show the required elongation (Section 13), all the rails of the melt shall be accepted.

(*c*) If two of the test pieces break at the first blow or do not show the required elongation (Section 13), all the top rails of the melt shall be rejected.

(*d*) A second test shall then be made from three test pieces selected by the inspector from the top end of any second rails or the bottom end of any top rails of the same melt, preferably of the same ingots. If two of the test pieces do not break at the first blow and both show the required elongation (Section 13), all the remaining rails of the melt shall be accepted.

(*e*) If two of these test pieces break at the first blow or do not show the required elongation (Section 13), all the second rails of the melt shall be rejected.

(*f*) A third test shall then be made from three test pieces selected by the inspector from the top end of any third rails or the bottom end of any second rails of the same melt, preferably of the same ingots. If two of the test pieces do not break at the first blow and both show the required elongation (Section 13), all the remaining rails of the melt shall be accepted.

(*g*) If two of these test pieces break at the first blow or do not show the required elongation (Section 13), all the remaining rails of the melt shall be rejected.

Examination of Fracture.

17. (*a*) The drop test pieces in a melt of Bessemer or open-hearth steel that have met the test requirements shall be nicked and broken for examination of interior structure of metal.

(*b*) If, in the judgment of the inspector, the appearance of the fracture of any test piece representing the top rails makes a separate classification advisable, all the top rails of the melt shall be designated and marked in accordance with Section 29 (*c*) and separated from other accepted rails of the melt.

(*c*) A second nick and break test shall then be made from test pieces as designated in Section 15 (*d*) or Section 16 (*d*) and if, in the judgment of the inspector, the appearance of the fracture of any test piece representing the second rails makes a separate classification advisable, all the second rails of the melt shall be marked and designated in accordance with Section 29 (*c*) and separated from other accepted rails of the melt.

(*d*) A third nick and break test shall then be made from test pieces as designated in Section 15 (*f*) or Section 16 (*f*) and if, in the judgment of the inspector, the appearance of the fracture of any test piece representing the third rails makes a separate classification advisable, all the remaining rails of the melt shall be marked and designated in accordance with Section 29 (*c*).

IV. STANDARD SECTION, LENGTH AND WEIGHT.

Section. 18. The section of the rails shall conform as accurately as possible to the templet furnished by the purchaser. A variation in height of $\frac{1}{64}$ in. less or $\frac{1}{32}$ in. greater than the specified height, and $\frac{1}{16}$ in. in width of base, will be permitted; but no variation shall be allowed in the dimensions affecting the fit of the splice bars.

Length. 19. The standard length of the rails shall be 33 ft., at a temperature of 60° F. Ten per cent of the entire order will be accepted in shorter lengths varying by 1 ft. from 32 to 25 ft. A variation of $\frac{1}{4}$ in. from the specified lengths will be allowed, except that for 15 per cent of the order a variation of $\frac{3}{8}$ in. from the specified lengths will be permitted.

Weight. 20. (*a*) The weight of the rails per yard as specified in the order shall be maintained as nearly as possible after conforming to the requirements of Section 18.

(*b*) The total weight of an order shall vary not more than 0.5 per cent from the calculated weight of section.

(*c*) Payments shall be based upon actual weights.

V. WORKMANSHIP AND FINISH.

Shrinkage. 21. The number of passes and speed of the train shall be so regulated that on leaving the rolls at the final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a rail 33 ft. in length, and of 100 lb. section, of

$6\frac{3}{4}$ in., and $\frac{1}{8}$ in. less for each 10 lb. decrease in section or $\frac{1}{8}$ in. more for each 10 lb. increase in section.

Cooling. 22. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass. Rails, while on the cooling beds, shall be protected from snow and water.

Straightening. 23. (*a*) The hot-straightening shall be carefully done, so that gagging under the cold presses will be reduced to a minimum. Any rails coming to the straightening presses showing sharp kinks or greater camber than that indicated by the middle ordinate of 4 in. in 33 ft. for A.R.A. type of sections, or 5 in. for A.S.C.E. type of sections, will be at once classed as No. 2 rails. The distance between the supports of rails in the straightening presses shall be not less than 42 in. The supports shall have flat surfaces and be out of wind.

(*b*) Rails heard to snap or check while being straightened shall be at once rejected.

Drilling. 24. Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser. A variation of $\frac{1}{32}$ in. in the specified size and location of bolt holes will be allowed.

Finishing. 25. (*a*) All rails shall be smooth on the heads, straight in line and surface, and without any twists, waves or kinks. They shall be sawed square at the ends, a variation of not more than $\frac{1}{32}$ in. being allowed, and burrs shall be carefully removed.

(*b*) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

(*c*) When any finished rail shows interior defect at either end, or in any drilled hole, the entire rail shall be rejected except that in the case of the bottom rails of the ingot permission shall be given to cut back to sound metal.

VI. CLASSIFICATION OF RAILS.

No. 1 Rails. 26. No. 1 rails shall be free from injurious defects and flaws of all kinds.

No. 2 Rails. 27. Rails which by reason of surface imperfections, or for causes mentioned in Section 23, are not classed as No. 1 rails, will be accepted as No. 2 rails; but No. 2 rails which contain imperfections in such number or of such character as will, in the judgment of the inspector, render them unfit for recognized No. 2 uses, will not be accepted for shipment. No. 2 rails to the extent of 5 per cent of the whole order will be accepted.

VII. MARKING.

Marking. 28. (*a*) The name of the manufacturer, the weight and type of section of rail, and the month and year of manufacture, shall be rolled in raised letters and figures on the side of the web. The number of the melt and a letter indicating the portion of the ingot from which the rail was made, shall be plainly stamped on the web of each rail, where it will not be covered by the splice bars. The top rails shall be lettered "A," and the succeeding ones "B," "C," "D," etc., consecutively; but in the case of a top discard of 20 or more per cent, the letter "A" will be omitted.

(*b*) Open-hearth rails shall be branded or stamped "O.H." in addition to the other marks.

(*c*) All marking of rails shall be done so effectively that the marks may be read as long as the rails are in service.

Special Marking. 29. (*a*) All rails accepted as No. 2 rails shall have the ends painted white and shall have two prick-punch marks on the side of the web near the melt number near the end of the rail so placed as not to be covered by the splice bars.

(*b*) No. 1 rails less than 33 ft. long shall have the ends painted green.

(*c*) Rails accepted in accordance with Section 17 shall have the ends painted blue and shall have three prick-punch marks on the side of the web near the melt number so placed as not to be covered by the splice bars.

Separate Classes. 30. All classes of rails shall be kept separate from each other.

VIII. INSPECTION.

Inspection. 31. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

STANDARD SPECIFICATIONS
FOR
OPEN-HEARTH STEEL GIRDER AND HIGH TEE RAILS.

Serial Designation: A 2 – 21.

These specifications are issued under the fixed designation A 2; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1912; Revised, 1921.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process. The entire process of manufacture and testing shall accord with the best current practice.

Bled Ingots. 2. Bled ingots, and ingots or blooms which show the effects of injurious treatment, shall not be used.

Discard. 3. A sufficient discard from the top of each ingot shall be made at any stage of the manufacture to obtain sound rails. When finished rails show piping, they may be cut to shorter lengths until all evidence of this is removed.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. The steel shall conform to either of the following requirements as to chemical composition, as specified in the order:

	Class A.	Class B.
Carbon, per cent	0.60 – 0.75	0.70 – 0.85
Manganese, per cent	0.60 – 0.90	0.60 – 0.90
Silicon, per cent	not over 0.20	not over 0.20
Phosphorus, per cent	" " 0.04	" " 0.04

Ladle Analyses. 5. To determine whether the material conforms to the requirements specified in Section 4, an analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. Drillings for analysis shall be taken not less than $\frac{1}{8}$ in. beneath the surface of the test ingot. A copy of this analysis shall be given to the purchaser or his representative.

Check Analyses. 6. A check analysis may be made from time to time by the purchaser from a test ingot or drillings therefrom furnished by the manufacturer.

III. PHYSICAL PROPERTIES AND TESTS.

Impression Test Specimens. 7. (*a*) Four representative sections of rail from each melt shall be selected by the inspector as test specimens.

(*b*) Excess scale on the head of the section shall be carefully removed.

Impression Test. 8. (*a*) The head of each specimen shall be subjected to a pressure of 50 net tons (100,000 lb.) for a period of 15 seconds, applied through a ball $\frac{3}{4}$ in. in diameter.

(*b*) The average depth of impression obtained on the four specimens shall not be more than 3.8 mm. for Class A rails, nor more than 3.6 mm. for Class B rails.

Retests. 9. If the average of the impression tests from any melt fails to conform to the requirements specified in Section 8 (*b*), the manufacturer may at his option test each rail from such melt by making an impression test on the web, as described in Section 8 (*a*). Rails so tested which conform to the requirements as to depth of impression specified in Section 8 (*b*) shall be accepted.

IV. STANDARD SECTIONS, LENGTHS, AND WEIGHTS.

Section. 10. (*a*) The cold templet of the manufacturer shall conform to the specified section as shown in detail on the drawing of the purchaser, and shall at all times be maintained perfect.

(*b*) The section of the rail shall conform as accurately as possible to the templet, and within the following tolerances:

(1) The height shall not vary more than $\frac{1}{64}$ in. under nor more than $\frac{1}{32}$ in. over that specified.

(2) The over-all width of head and tram shall not vary more than $\frac{1}{8}$ in. from that specified. Any variation which would affect the gage line more than $\frac{1}{32}$ in. will not be allowed.

(3) The width of base shall not vary more than $\frac{1}{8}$ in. under that specified for widths less than $6\frac{1}{2}$ in.; $\frac{3}{16}$ in. under for a width of $6\frac{1}{2}$ in.; and $\frac{1}{4}$ in. under for a width of 7 in.

(4) Any variation which would affect the fit of the splice bars will not be allowed.

(5) The base of the rail shall be at right angles to the web; and the convexity shall not exceed $\frac{1}{32}$ in.

(*c*) When necessary on account of the type of track construction, and notice to that effect has been given to the manufacturer, special care shall be taken to maintain the proper position of the gage line with respect to the outer edge of the base.

Length.

11. (*a*) Unless otherwise specified, the lengths of rails at a temperature of 60° F. shall be 60 and 62 ft. for those sections in which the weight per yard will permit.

(*b*) The lengths shall not vary more than $\frac{1}{4}$ in. from those specified.

(*c*) Shorter lengths, varying by even feet down to 40 ft., will be accepted to the extent of 10 per cent by weight of the entire order.

Weight.

12. (*a*) The weight of the rails per yard as specified in the order shall be maintained as nearly as possible after conforming to the requirements specified in Section 11.

(*b*) The total weight of an order shall not vary more than 0.5 per cent from that specified.

(*c*) Payments shall be based on actual weights.

V. WORKMANSHIP AND FINISH.

Straightening.

13. (*a*) Rails on the hot beds shall be protected from water or snow, and shall be carefully manipulated to minimize cold straightening.

(*b*) The distance between the rail supports in the cold-straightening presses shall not be less than 42 in., except as may be necessary near the ends of the rails. The gag shall have rounded corners to avoid injury to the rails.

Drilling and Punching.

14. (*a*) Circular holes for joint bolts, bonds, and tie rods shall be drilled to conform to the drawings and dimensions furnished by the purchaser.

(*b*) In Class A rails the tie-rod holes may be punched.

Milling.

15. The ends shall be milled square laterally and vertically, but the base may be undercut $\frac{1}{32}$ in.

Finish.

16. (*a*) Rails shall be smooth on the head, straight in line and surface without any twists, waves, or kinks, particular attention being given to having the ends without kinks or drop.

(*b*) All burrs or flow caused by drilling or sawing shall be carefully removed.

(*c*) Rails shall be free from gag marks and other injurious defects of cold-straightening.

VI. CLASSIFICATION OF RAILS.

No. 1 Rails.

17. Rails which are free from injurious defects and flaws of all kinds shall be classed as No. 1 Rails.

No. 2 Rails. 18. (*a*) Rails which are rough on the head or which by reason of surface or other imperfections are not classed as No. 1 rails, shall be classed as No. 2 rails; provided they do not, in the judgment of the inspector, contain imperfections in such number and of such character as to render them unfit for No. 2 rail uses, and provided they conform to the requirements specified in Section 11.

(*b*) Rails which have flaws in the head exceeding ¼ in. in depth, or in the base exceeding ½ in. in depth, shall not be classed as No. 2 rails.

(*c*) No. 2 rails will be accepted to the extent of 10 per cent by weight of the entire order.

VII. MARKING AND LOADING.

Marking. 19. (*a*) The name or brand of the manufacturer, the year and month of manufacture, the letters "O. H.," the weight of the rail, and the section number, shall be legibly rolled in raised letters and figures on the web. The melt number shall be legibly stamped on each rail where it will not be covered subsequently by the joint plates.

(*b*) Both ends of all short-length No. 1 rails shall be painted green.

Both ends of all No. 2 rails shall be painted white and shall have two heavy center-punch marks on the web at each end at such a distance from the end that they will not be covered subsequently by the joint plates.

Loading. 20. (*a*) Rails shall be loaded in the presence of the inspector, and shall be handled in such a manner as not to bruise the flanges or cause other injuries.

(*b*) Rails of each class shall be placed together in loading.

(*c*) Rails shall be paired as to length before shipment.

VIII. INSPECTION.

Inspection. 21. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

STANDARD SPECIFICATIONS
FOR
LOW-CARBON-STEEL SPLICE BARS.

Serial Designation: A 3 – 14.

These specifications are issued under the fixed designation A 3; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914.

I. MANUFACTURE.

Process. 1. The steel shall be made by either or both the following processes: Bessemer or open-hearth.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 2. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Bessemer	not over 0.10 per cent
	Open-hearth	" " 0.05 "

Ladle Analyses. 3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

Check Analyses. 4. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 5. The splice bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55 000 – 65 000
Elongation in 8 in., min., per cent	25

Bend Tests. 6. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens. 7. Tension and bend test specimens shall be taken from the finished rolled bars. Tension test specimens shall be of 8-in. gage length. Bend tests may be made of an unpunched splice bar, flattened if necessary.

Number of Tests. 8. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. WORKMANSHIP AND FINISH.

Workmanship. 9. (*a*) The splice bars shall be smoothly rolled, true to templet, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size and location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish. 10. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 11. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

VI. INSPECTION AND REJECTION.

Inspection. 12. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

13. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

14. Samples tested in accordance with Section 4, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
MEDIUM-CARBON-STEEL SPLICE BARS.

Serial Designation: A 4 – 14.

These specifications are issued under the fixed designation A 4; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

Finishing. 2. (*a*) The splice bars may be punched, slotted, and, in the case of special designs, shaped either hot or cold.

(*b*) Bars that are punched, slotted or shaped cold shall be subsequently annealed.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Carbon..........................	not under	0.30	per cent
Phosphorus......................	not over	0.04	"

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. The splice bars shall conform to the following minimum requirements as to tensile properties:

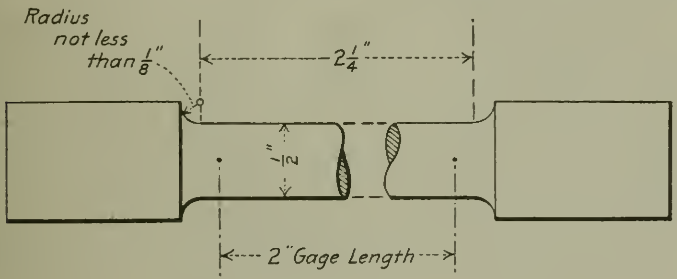
Tensile strength, lb. per sq. in.	68 000
Elongation in 2 in., per cent. . . . . but in no case under 20 per cent.	$\frac{1\,600\,000}{\text{Tens. str.}}$

Bend Tests.

7. The bend test specimen specified in Section 8 shall bend cold through 180 deg. around a pin the diameter of which is equal to twice the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens.

8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be ½ in. square in section, or rectangular in section with two parallel faces as rolled.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

Optional Bend Tests.

9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 7: A piece of the finished bar shall bend cold through 90 deg. around a pin the diameter of which is equal to twice the greatest thickness of the section, without cracking on the outside of the bent portion.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. WORKMANSHIP AND FINISH.

Workmanship.

11. (*a*) The splice bars shall be smoothly rolled, true to templet, and shall accurately fit the rails for which they are intended The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish.

12. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking.

13. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

VI. INSPECTION AND REJECTION.

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
HIGH-CARBON-STEEL SPLICE BARS.

Serial Designation: A 5 – 14.

These specifications are issued under the fixed designation A 5; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1913; Revised, 1914.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

Finishing. 2. The splice bars shall be punched, slotted and, in the case of special designs, shaped at a temperature not less than 750° C.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Carbon	not under	0.45	per cent.
Phosphorus	not over	0.04	"

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. The splice bars shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in	85 000
Elongation in 2 in., per cent	14

Bend Tests.

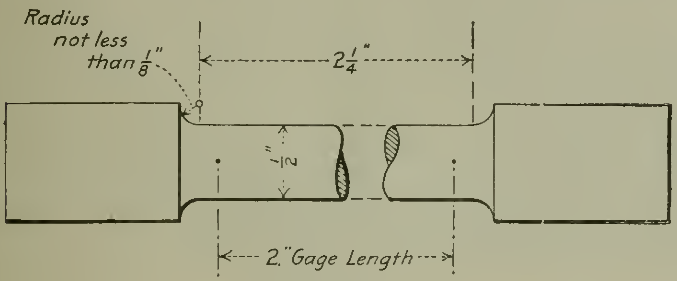
7. The bend test specimen specified in Section 8 shall bend cold through 90 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens.

8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be ½ in. square in section, or rectangular in section with two parallel faces as rolled.

Optional Bend Tests.

9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 7: A piece of the finished bar shall bend cold through 45 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than ¾ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. WORKMANSHIP AND FINISH.

Workmanship. 11. (*a*) The splice bars shall be smoothly rolled, true to templet, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish. 12. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 13. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

VI. INSPECTION AND REJECTION.

Inspection. 14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
EXTRA-HIGH-CARBON-STEEL SPLICE BARS.

Serial Designation: A 6 – 14.

These specifications are issued under the fixed designation A 6; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1913; Revised, 1914.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

Finishing. 2. The splice bars shall be punched, slotted, sheared and, in the case of special designs, shaped at a temperature not less than 750° C.; except that bars may be cold-sawed to length.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirement as to chemical composition:

Phosphorus	not over 0.04 per cent

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirement specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. The splice bars shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	100 000
Elongation in 2 in., per cent	10

Bend Tests.

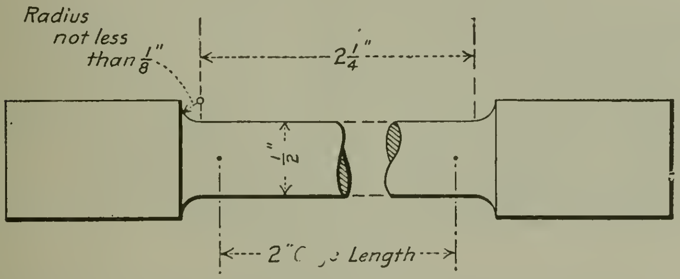
7. The bend test specimen specified in Section 8 shall bend cold through 60 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens.

8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be $\frac{1}{2}$ in. square in section, or rectangular in section with two parallel faces as rolled.

Optional Bend Tests.

9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 7: A piece of the finished bar shall bend cold through 30 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. WORKMANSHIP AND FINISH.

Workmanship. 11. (*a*) The splice bars shall be smoothly rolled, true to templet, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish. 12. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 13. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

VI. INSPECTION AND REJECTION.

Inspection. 14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS
FOR
QUENCHED HIGH-CARBON-STEEL SPLICE BARS.

Serial Designation: A 49-21.

These specifications are issued under the fixed designation A 49; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1921.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

Finishing and Heat Treatment 2. The splice bars shall be punched, slotted and, in the case of special designs, shaped at a temperature not less than 750° C., and subsequently quenched.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Carbon	not over 0.60 per cent
Manganese	" " 0.80 "
Phosphorus	" " 0.04 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

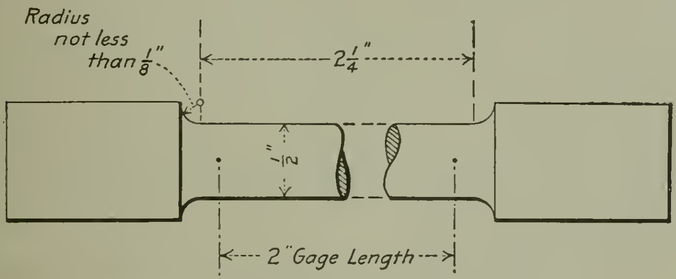
Tension Tests. 6. (*a*) The splice bars shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	100 000
Yield point, " "	65 000
Elongation in 2 in., per cent	10

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests. 7. The bend test specimen specified in Section 8 shall bend cold through 90 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens. 8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be ½ in. square in section, or rectangular in section with two parallel faces as rolled, with corners rounded to a radius not over $\frac{1}{16}$ in.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

Optional Bend Tests. 9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 7: A piece of the finished bar shall bend cold through 45 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.

Number of Tests. 10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 11. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

IV. WORKMANSHIP AND FINISH.

Workmanship. 12. The splice bars shall be smoothly rolled, true to templet, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish. 13. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 14. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

VI. INSPECTION AND REJECTION.

Inspection. 15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS

FOR

QUENCHED CARBON-STEEL TRACK BOLTS.

Serial Designation: A 50–21.

These specifications are issued under the fixed designation A 50; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1915; Revised, 1916, 1921.

I. MANUFACTURE.

Process. 1. (*a*) The steel for the bolts shall be made by the open-hearth process.

(*b*) The steel for the nuts shall be made by either or both the following processes: Bessemer or open-hearth.

Finishing and Heat Treatment. 2. The bolts shall enter the quenching medium at a temperature not less than 790° C. The threads may be rolled either hot or cold.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel for the bolts shall conform to the following requirements as to chemical composition:

Carbon	not under 0.30 per cent
Phosphorus	not over 0.04 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bolt representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

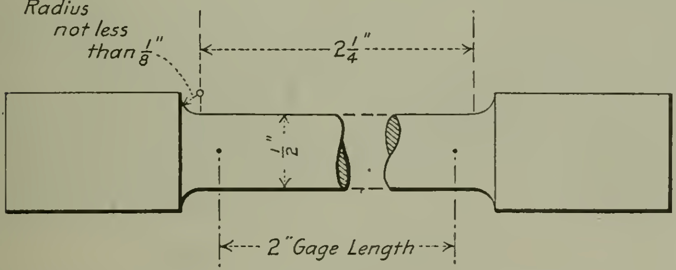
Tension Tests. 6. (*a*) The bolts shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	100 000
Yield point, " "	70 000
Elongation in 2 in., per cent	12

(*b*) Nuts shall be capable of developing the strength of the finished bolt up to its yield point.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests. 7. Full-size bolts shall bend cold through 45 deg. around a pin the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

Test Specimens. 8. Tension test specimens shall be taken from the finished bolts and shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests. 9. (*a*) One tension and one bend test shall be made from each lot of 50 kegs or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, or if the bend test specimen breaks in the threaded portion, a retest shall be allowed.

Retests.

10. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot one or more times in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

IV. PERMISSIBLE VARIATION.

Permissible Variations.

11. The bolts and nuts shall conform to the dimensions specified by the purchaser subject to the following variations: A variation of $\frac{1}{32}$ in. under and $\frac{1}{64}$ in. over the specified diameter of the shank of the bolt will be permitted. The diameter of rolled thread shall not exceed the diameter of the shank more than $\frac{1}{16}$ in. for bolts $\frac{7}{8}$ in. in diameter and under, nor more than $\frac{3}{32}$ in. for bolts 1 in. in diameter and over. The outside diameter of the finished rolled threads shall not exceed the diameter of the shank of a cut thread bolt of corresponding size. The length of the bolt under the head shall not vary more than $\frac{1}{8}$ in. from that specified. A variation in the dimensions of the elliptical shoulders under the head of $\frac{1}{32}$ in. and a taper of the shoulder of $\frac{1}{32}$ in. will be permitted.

V. WORKMANSHIP AND FINISH.

Workmanship.

12. The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly joined to the shank, with the under side at right angles to the axis of the bolt. The threads shall be sharp and true to gage and of the design specified by the purchaser. The nuts shall have a hand free fit on the bolt from two to six turns, and wrench tight the balance of the screw length without distorting the threads or twisting the shank. They shall be screwed on the bolts before packing, a sufficient number of turns to hold them in place until used.

Finish.

13. The finished bolts and nuts shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking.

14. A letter or brand indicating the manufacturer shall be pressed on the head of the bolt when it is formed.

VII. INSPECTION AND REJECTION.

Inspection. 15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolts and nuts ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bolts and nuts are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as to not interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 17. Samples tested in accordance with Section 5, which represent rejected bolts and nuts, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
QUENCHED ALLOY-STEEL TRACK BOLTS.

Serial Designation: A 51 – 21.

These specifications are issued under the fixed designation A 51; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1916, 1921.

I. MANUFACTURE.

Process. 1. (*a*) The steel for the bolts shall be made by either or both the following processes: open-hearth or electric furnace.

(*b*) The steel for the nuts shall be made by either or both the following processes: Bessemer or open-hearth.

Finishing and Heat Treatment. 2. The bolts shall enter the quenching medium at a temperature of not less than 790° C. The threads may be rolled either hot or cold.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel for the bolts shall conform to the following requirement as to chemical composition:

Phosphorus........................ not over 0.035 per cent.

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur, and any other elements used to obtain the physical properties specified in Sections 6 and 7. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirement specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bolt representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. (*a*) The bolts shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	110 000
Yield point, " "	85 000
Elongation in 2 in., per cent	12

(*b*) Nuts shall be capable of developing the full strength of the finished bolt up to its yield point.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests. 7. Full-size bolts shall bend cold through 90 deg. around a pin the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion.

Test Specimens. 8. Tension test specimens shall be taken from the finished bolts and shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests. 9. (*a*) One tension and one bend test shall be made from each lot of 50 kegs or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, or if the bend test specimen breaks in the threaded portion, a retest shall be allowed.

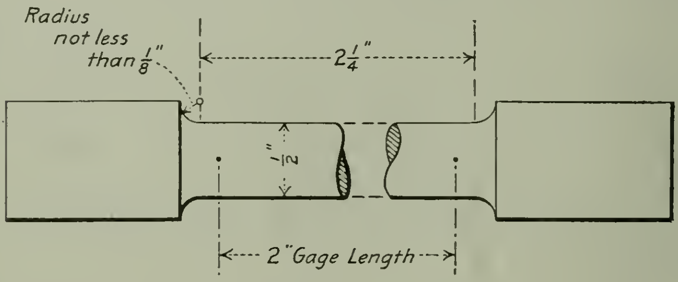
Retests. 10. If the results of the physical tests of any test lot do not conform to the requirements specified, two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

IV. PERMISSIBLE VARIATIONS.

Permissible Variations. 11. The bolts and nuts shall conform to the dimensions specified by the purchaser subject to the following variations: A variation of $\frac{1}{32}$ in. under and $\frac{1}{64}$ in. over the specified diameter of the shank of the bolt will be permitted. The diameter of rolled thread shall not exceed the diameter of the shank more than $\frac{1}{16}$ in. for bolts $\frac{7}{8}$ in. in diameter and under, nor more than $\frac{3}{32}$ in. for bolts 1 in. in diameter and over. The outside diameter of the finished rolled threads shall not exceed the diameter of the shank of a cut thread bolt of corresponding size. The length of the bolt under the head shall not vary more than $\frac{1}{8}$ in. from that specified. A variation in the dimensions of the elliptical shoulders under the head of $\frac{1}{32}$ in. and a taper of the shoulder of $\frac{1}{32}$ in. will be permitted.

V. WORKMANSHIP AND FINISH.

Workmanship. 12. The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly joined to the shank, with the under side at right angles to the axis of the bolt. The threads shall be sharp and true to gage and of the design specified by the purchaser. The nuts shall have a hand free fit on the bolt from two to six turns, and wrench tight the balance of the screw length without distorting the threads or twisting the shank. They shall be screwed on the bolts before packing, a sufficient number of turns to hold them in place until used.



Note :– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

Finish. 13. The finished bolts and nuts shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 14. A letter or brand indicating the manufacturer shall be pressed on the head of the bolt when it is formed.

VII. INSPECTION AND REJECTION.

Inspection. 15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolts and nuts ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bolts and nuts are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as to not interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 17. Samples tested in accordance with Section 5, which represent rejected bolts and nuts, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STEEL TRACK SPIKES.

Serial Designation: A 65 – 18.

These specifications are issued under the fixed designation A 65; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1916; ADOPTED, 1918.

I. MANUFACTURE.

Process. 1. The steel shall be made by either or both the following processes: Bessemer or open-hearth.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 2. The full-size finished spikes, or the full-size bars from which the spikes are made, shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55 000
Yield point, lb. per sq. in.	0.5 tens. str.
Elongation in 2 in., per cent	25

Bend Tests. 3. (*a*) The body of the full-size finished spikes shall bend cold through 180 deg. flat on itself, without cracking on the outside of the bent portion.

(*b*) The head of the full-size finished spikes shall bend backward to the line of the face of the spike, without cracking on the outside of the bent portion.

Number of Tests. 4. (*a*) One tension and one bend test of each kind shall be made from each lot of 10 tons or fraction thereof.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

Retests. 5. If any tension test specimen breaks more than $\frac{3}{4}$ in. from the center of the gage length, a retest shall be allowed.

III. WORKMANSHIP AND FINISH.

Workmanship. 6. The spikes shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{64}$ in. under the specified dimension of the body of the spike, measured from the face to the back, and a variation of $\frac{1}{32}$ in. over the specified dimension of the body of the spike, measured across the face, will be permitted. A variation of $\frac{3}{32}$ in. over and $\frac{1}{32}$ in. under the specified dimensions of the head of the spike will be permitted. A variation of $\frac{1}{8}$ in. from the specified length of the spike, measured from the under side of the head to the point, will be permitted. A variation of 1 deg. in the specified angle of the under side of the head of the spike will be permitted.

Finish. 7. The finished spikes shall be free from injurious defects and shall have a workmanlike finish.

V. INSPECTION AND REJECTION.

Inspection. 8. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the spikes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the spikes are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 9. Spikes which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
STEEL SCREW SPIKES.

Serial Designation: A 66 – 21.

These specifications are issued under the fixed designation A 66; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1916; Adopted, 1918; Revised, 1921.

I. MANUFACTURE.

Process. 1. The steel shall be made by either or both the following processes: Bessemer or open-hearth.

Finishing. 2. The heads of the spikes shall be formed and the threads rolled at a temperature not less than 750° C.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 3. The full-size finished spikes shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	60 000
Yield point, lb. per sq. in.	0.5 tens. str.
Elongation in 2 in., per cent	20

Bend Tests. 4. The full-size finished spikes shall bend cold through 90 deg. around a pin the diameter of which is equal to three times the diameter of the spike, without cracking on the outside of the bent portion.

Number of Tests. 5. (*a*) One tension and one bend test shall be made from each lot of 100 kegs or fraction thereof.

(*b*) If any spike tested develops flaws, it may be discarded and another spike substituted.

Retests. 6. (*a*) If the percentage of elongation of any tension test spike is less than that specified in Section 3, a retest shall be allowed.

(*b*) If any tension test spike breaks more than $\frac{3}{4}$ in. from the center of the gage length, a retest shall be allowed.

III. WORKMANSHIP AND FINISH.

Workmanship. 7. The spikes shall conform to the dimensions specified by the purchaser. The head shall be concentric with, and firmly joined to, the body of the spike. The threads shall be sharp and true to gage and of the design specified by the purchaser. A variation of $\frac{1}{32}$ in. over the specified diameter of the unthreaded portion of the body of the spike will be permitted. A variation of $\frac{1}{32}$ in. over the specified diameter of the threaded portion of the spike will be permitted. A variation of $\frac{1}{16}$ in. under and $\frac{1}{8}$ in. over in the reach of the head of the spike will be permitted. A variation of $\frac{1}{8}$ in. from the specified length of the spike will be permitted.

8. The finished spikes shall be free from injurious defects and shall have a workmanlike finish. **Finish.**

IV. MARKING.

9. A letter or brand indicating the manufacturer shall be pressed on the head of the spike while it is being formed. **Marking.**

V. INSPECTION AND REJECTION.

10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the spikes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the spikes are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

11. Spikes which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified. **Rejection.**

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR BRIDGES.

Serial Designation: A 7–21.

These specifications are issued under the fixed designation A 7; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1901; Revised, 1905, 1909, 1913, 1914, 1915, 1916, 1921.

Steel Castings. 1. The Standard Specifications for Steel Castings (Serial Designation: A 27), adopted by the American Society for Testing Materials, shall govern the purchase of steel castings for bridges. Unless otherwise specified, Class B castings, medium grade, shall be used.

I. MANUFACTURE.

Process. 2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

		Structural Steel.	Rivet Steel.
Phosphorus	Acid	not over 0.06	not over 0.04 per cent
	Basic	" " 0.04	" " 0.04 "
Sulfur		" " 0.05	" " 0.045 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall no exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered.	Structural Steel.	Rivet Steel.
Tensile strength, lb. per sq. in.	55 000 - 65 000[a]	46 000 - 56 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$[b]	$\frac{1\,500\,000}{\text{Tens. str.}}$
Elongation in 2 in., " "	22	....

[a] See Paragraph (*b*).
[b] See Section 7.

(*b*) In order to meet the required minimum tensile strength of full-size annealed eyebars, the purchaser may determine the tensile strength to be obtained in specimen tests; the range shall not exceed 14,000 lb. per sq. in., and the maximum shall not exceed 74,000 lb. per sq. in. The material shall conform to the requirements as to physical properties other than that of tensile strength, specified in Sections 6, 7 and 8(*b*).

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. (*a*) For structural steel over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. in thickness below $\frac{5}{16}$ in.

Bend Tests.

8. (*a*) The test specimen for plates, shapes, and bars, except as specified in Paragraphs (*b*), (*c*) and (*d*), shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for eyebar flats shall bend cold through 180 deg. without cracking on the outside of the bent portion as follows: For material $\frac{3}{4}$ in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

(*c*) The 1 by $\frac{1}{2}$-in. test specimen for pins, rollers and other bars, when prepared as specified in Section 9, shall bend cold through 180 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

(*d*) The test specimen for rivet steel shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

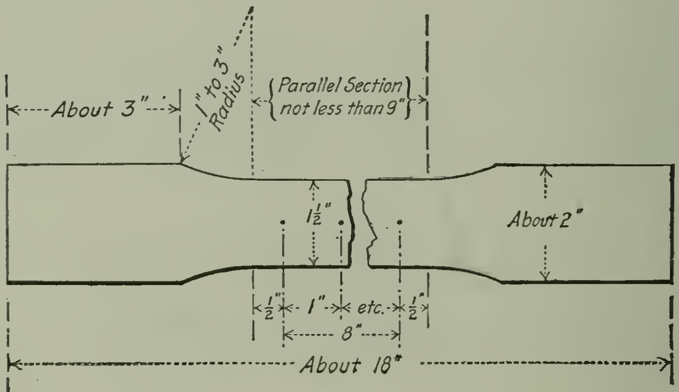


FIG. 1.

Test Specimens. 9. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*), (*e*) and (*f*) shall be of the full thickness or diameter of material as rolled.

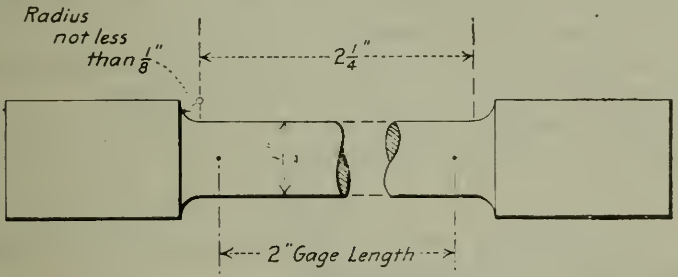
(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel; except that bend test specimens for eyebar flats may have three rolled sides.

(*d*) Tension test specimens for plates and eyebar flats over $1\frac{1}{2}$ in. in thickness, and bend test specimens for plates over $1\frac{1}{2}$ in.

in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*e*) Test specimens for bars over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by $\frac{1}{2}$ in. in section.

(*f*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be 1 by $\frac{1}{2}$ in. in section.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

(*g*) The tension test specimen shown in Fig. 2 and the 1 by $\frac{1}{2}$-in. bend test specimen for pins and rollers shall be taken so that the axis is 1 in. from the surface; and for other bars over $1\frac{1}{2}$ in. in thickness or diameter, midway between the center and surface.

(*h*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

(*i*) Test specimens for rivet bars which have been cold drawn shall be normalized before testing.

Number of Tests

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6(*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

11. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

V. FINISH.

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking.

13. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅓ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108in., excl.	108 to 120in., excl.	120 to 132in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL NICKEL STEEL.

Serial Designation: A 8-21.

These specifications are issued under the fixed designation A 8; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1912; Revised, 1913, 1914, 1916, 1921.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

Discard. 2. A sufficient discard shall be made from each ingot intended for eyebars to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

		Structural Steel.	Rivet Steel.
Carbon		not over 0.45	not over 0.30 per cent
Manganese		" " 0.70	" " 0.60 "
Phosphorus	Acid	" " 0.05	" " 0.04 "
	Basic	" " 0.04	" " 0.03 "
Sulfur		" " 0.05	" " 0.045 "
Nickel		not under 3.25	not under 3.25 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. Analyses may be made by the purchaser from finished material representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS

Tension Tests

6. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered.	Rivet Steel.	Plates, Shapes and Bars.	Eyebar flats and Rollers,[c] Unannealed.	Eyebar flats[a] and Pins,[c] Annealed
Tensile strength, lb. per sq. in.	70 000 – 80 000	85 000 – 100 000	95 000 – 110 000	90 000 – 105 000
Yield point, min., lb. per sq. in.	45 000	50 000	55 000	52 000
Elongation in 8 in., min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000^{b}}{\text{Tens. str.}}$	$\frac{1\,500\,000^{b}}{\text{Tens. str.}}$	20
Elongation in 2 in., min., per cent	....	....	16	20
Reduction of area, min., per cent	40	25	25	35

[a] Tests of annealed specimens of eyebar flats shall be made for information only.

[b] See Section 7.

[c] Elongation shall be measured in 2 in.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. For plates, shapes, and unannealed bars over 1 in. in thickness, a deduction from the percentage of elongation specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above 1 in., to a minimum of 14 per cent.

Character of Fracture.

8. All broken tension test specimens shall show either a silky or a very fine granular fracture, of uniform color, and free from coarse crystals.

Bend Tests.

9. (*a*) The test specimen for plates, shapes and bars shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $\frac{3}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for pins and rollers shall bend cold through 180 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

(*c*) The test specimen for rivet steel shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Drift Tests.

10. Punched rivet holes pitched two diameters from a planed edge shall stand drifting until the diameter is enlarged 50 per cent, without cracking the metal.

Test Specimens.

11. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*), (*e*) and (*f*) shall be of the full thickness or diameter of material as rolled.

(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel; except that bend test specimens for eyebar flats may have three rolled sides.

(*d*) Tension test specimens for plates and eyebar flats over 1½ in. in thickness, and bend test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

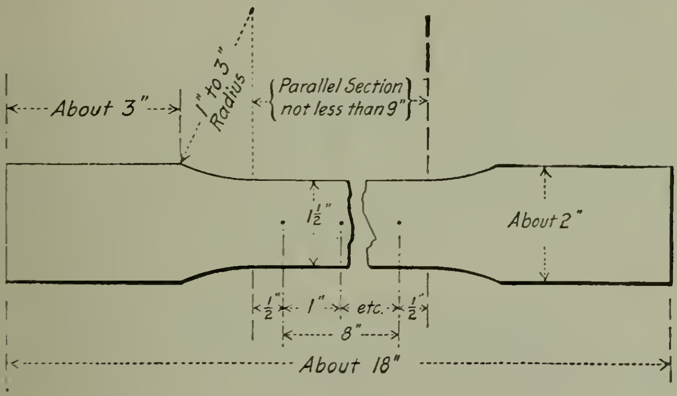


FIG. 1.

(*e*) Test specimens for bars over 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by ½ in. in section.

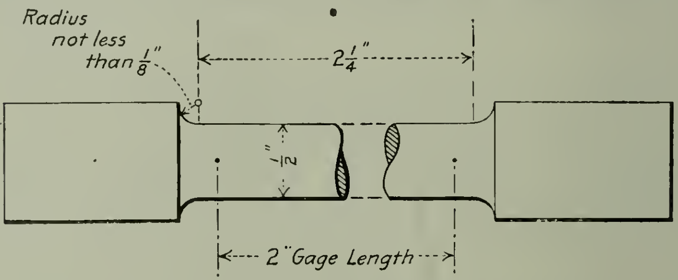
(*f*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be 1 by ½ in. in section.

(*g*) The tension test specimen shown in Fig. 2 and the 1 by $\frac{1}{2}$-in. bend test specimen for pins and rollers shall be taken so that the axis is 1 in. from the surface; and for other bars over $1\frac{1}{2}$ in. in thickness or diameter, midway between the center and surface.

(*h*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

(*i*) Test specimens for rivet bars which have been cold drawn shall be normalized before testing.

Number of Tests. 12. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations. 13. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

V. FINISH.

Finish.

14. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking.

15. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection

16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

Ordered Weight, lb. per sq. ft.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights.																		Ordered Weight, lb. per sq. ft.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1¼ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

18. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

VIII. FULL-SIZE TESTS.

Tests of Eyebars.

19. (*a*) Full-size tests of annealed eyebars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	85 000-100 000
Yield point, min., " "	48 000
Elongation in 18 ft., min., per cent	10
Reduction of area, " "	30

(*b*) The yield point shall be determined by the halt of the gage of the testing machine.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR BUILDINGS.

Serial Designation: A 9–21.

These specifications are issued under the fixed designation A 9; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1901; Revised, 1909, 1913, 1914, 1916, 1921.

I. MANUFACTURE.

Process. 1. (*a*) Structural steel, except as noted in Paragraph (*b*), shall be made by either or both the following processes: Bessemer or open-hearth.

(*b*) Rivet steel, and steel for plates or angles over ¾ in. in thickness which are to be punched, shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 2. The steel shall conform to the following requirements as to chemical composition:

		Structural Steel.	Rivet Steel.
Phosphorus	Bessemer	not over 0.10 per cent	......
	Open-hearth...	" " 0.06 "	not over 0.06 per cent
Sulfur		....	" " 0.045 "

Ladle Analyses. 3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

Check Analyses. 4. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

5. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered.	Structural Steel.	Rivet Steel
Tensile strength, lb. per sq. in.	55 000 – 65 000	46 000 – 56 000
Yield point, min.. " "	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent............	$\frac{1\,400\,000}{\text{Tens. str.}}$ [a]	$\frac{1\,400\,000}{\text{Tens. str.}}$
Elongation in 2 in. " "	22	....

[a] See Section 6.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

6. (*a*) For structural steel over ¾ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 5(*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above ¾ in., to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 5(*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

7. (*a*) The test specimen for plates, shapes and bars, except as specified in Paragraphs (*b*) and (*c*), shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material ¾ in. or under in thickness, flat on itself; for material over ¾ in. to and including 1¼ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1¼ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The 1 by ½-in. test specimen for pins, rollers and other bars, when prepared as specified in Section 8, shall withstand being bent cold through 180 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

(*c*) The test specimen for rivet steel shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

8. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*), (*e*) and (*f*) shall be of the full thickness or diameter of material as rolled.

(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

(*e*) Test specimens for bars over 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by ½ in. in section.

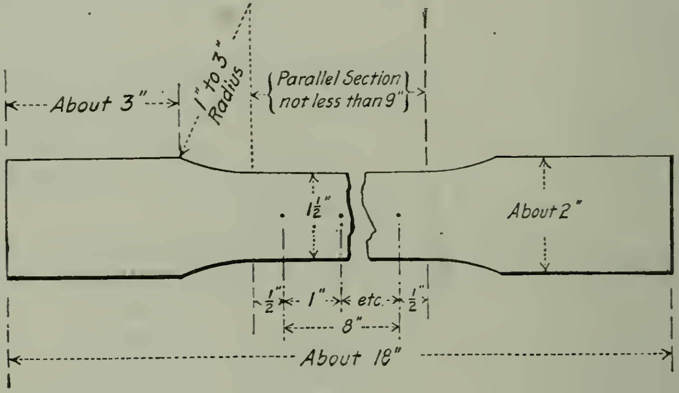


FIG. 1.

(*f*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be 1 by ½ in. in section.

(*g*) The tension test specimen shown in Fig. 2 and the 1 by ½-in. bend test specimen for pins and rollers shall be taken so that the axis is 1 in. from the surface; and for other bars over 1½ in. in thickness or diameter, midway between the center and surface.

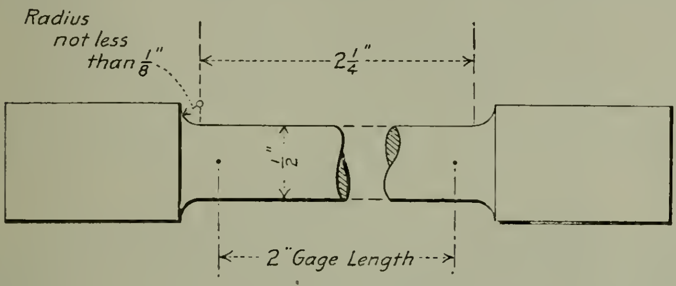
(*h*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

(*i*) Test specimens for rivet bars which have been cold drawn shall be normalized before testing.

Number of Tests. 9. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is more than ¾ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.



Note:—The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations. 10. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1¼ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

V. FINISH.

11. The finished material shall be free from injurious defects and shall have a workmanlike finish. **Finish.**

VI. MARKING.

12. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen. **Marking.**

VII. INSPECTION AND REJECTION.

13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturers' works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

15. Samples tested in accordance with Section 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

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[1] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR LOCOMOTIVES.

Serial Designation: A 10 – 21.

These specifications are issued under the fixed designation A 10; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916, 1921.

Basis of Purchase. 1. These specifications apply to shapes, plates (except boiler and firebox plates) and bars over $\frac{1}{8}$ in. in thickness or diameter.

I. MANUFACTURE.

Process. 2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	not over 0.05 per cent
Sulfur	" " 0.06 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. (*a*) The material shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55 000 – 65 000
Yield point min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent (See Section 7)	$\frac{1\,500\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

(*c*) Plates $\frac{3}{16}$ in. or under in thickness shall not be subject to tension tests.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

8. The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Test Specimens.

9. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*) and (*e*), shall be of the full thickness or diameter of material as rolled.

(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Test specimens for plates over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*e*) Test specimens for bars over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by $\frac{1}{2}$ in. in section.

(*f*) The tension test specimen shown in Fig. 2 and the 1 by $\frac{1}{2}$-in. bend test specimen for bars over $1\frac{1}{2}$ in. in thickness or diameter shall be taken so that the axis is midway between the center and surface.

(*g*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or over in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled. Shapes less than 1 sq. in. in section, and bars less than $\frac{1}{2}$ sq. in. in section, need not be subjected to a tension test.

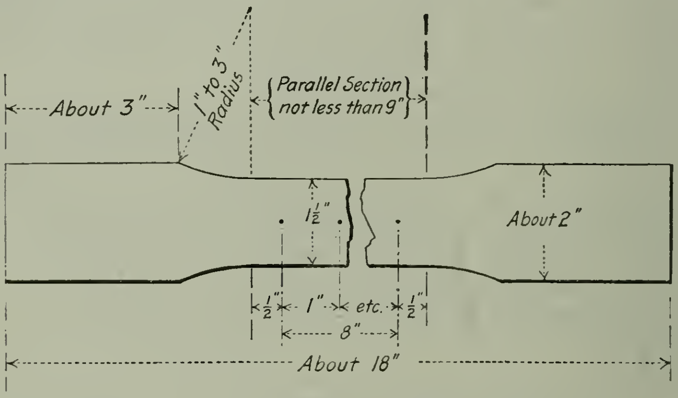


FIG. 1.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

11. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the

case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

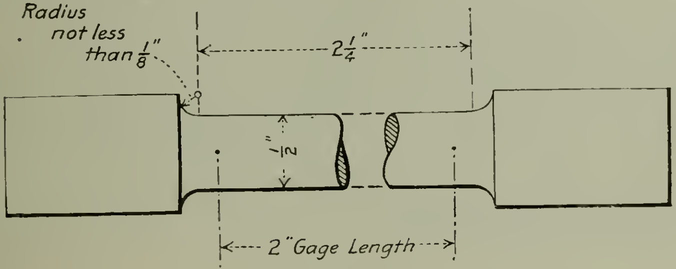
(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

V. FINISH.

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

VI. MARKING.

Marking.

13. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that small sections shall, when loaded for shipment, be properly separated and marked for identification. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the pur-

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[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅓ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

chaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR CARS.

Serial Designation: A 11-21.

These specifications are issued under the fixed designation A 11; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1916, 1921.

Material Covered. 1. These specifications apply to shapes, plates and bars over $\frac{1}{8}$ in. in thickness or diameter.

I. MANUFACTURE.

Process. 2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

		STRUCTURAL STEEL AND PLATES FOR COLD PRESSING.	RIVET STEEL.	
Phosphorus	Acid	not over 0.06	not over 0.04	per cent
	Basic	" " 0.04	" " 0.04	"
Sulfur		" " 0.06	" " 0.045	"

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. (*a*) The material except as specified in Paragraph (*c*) shall conform to the following requirements as to tensile properties:

Properties Considered.	Structural Steel.	Rivet Steel.	Plates for Cold Pressing.
Tensile strength, lb. per sq. in.	50 000 – 65 000	45 000 – 60 000	48 000 – 58 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent[1]	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$

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[1] See Section 7.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

(*c*) Plates $\frac{3}{16}$ in. or under in thickness shall not be subject to tension tests.

Modifications in Elongation. 7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests. 8. (*a*) The test specimen for structural steel shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for rivet steel and plates for cold pressing shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens. 9. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*) and (*e*), shall be of the full thickness or diameter of material as rolled.

(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Test specimens for plates over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*e*) Test specimens for bars over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by $\frac{1}{2}$ in. in section.

(*f*) The tension test specimen shown in Fig. 2 and the 1 by $\frac{1}{2}$-in. bend test specimen for bars over $1\frac{1}{2}$ in. in thickness or diameter shall be taken so that the axis is midway between the center and surface.

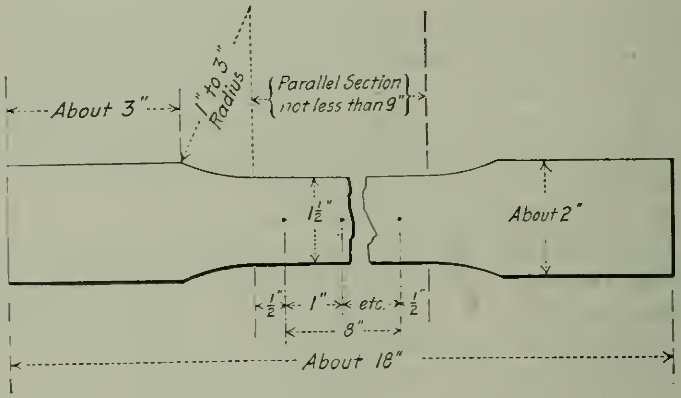


FIG. 1.

(*g*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

(*h*) Test specimens for rivet bars which have been cold drawn shall be normalized before testing.

Number of Tests. 10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled. Shapes less than 1 sq. in. in section, and bars, except rivet rods, less than $\frac{1}{2}$ sq. in. in section, need not be subjected to a tension test.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

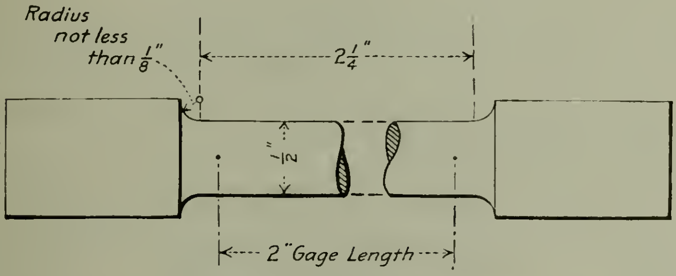
(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

11. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.



Note:—The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

V. FINISH.

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

Ordered Weight, lb. per sq. ft.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights.																		Ordered Weight, lb. per sq. ft.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1¼ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

VI. MARKING.

13. The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material, except that rivet bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The melt number shall be legibly marked, by stamping if practicable, on each test specimen. **Marking.**

VII. INSPECTION AND REJECTION.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR SHIPS.[1]

Serial Designation: A 12 – 21.

These specifications are issued under the fixed designation A 12; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916, 1921.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 2. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	not over 0.06 per cent
	Basic	" " 0.04 "
Sulfur		" " 0.06 "

Ladle Analyses. 3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

Check Analyses. 4. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 5. (*a*) The material shall conform to the following requirements as to tensile properties:

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[1] NOTE.—The requirements for castings for ships have been especially provided for in the Standard Specifications for Steel Castings (Serial Designation: A 27), adopted by the American Society for Testing Materials (see pp. 200–204).

Tensile strength, lb. per sq. in.	58 000 – 68 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent (See Section 6.)	$\frac{1\,500\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

6. (*a*) For material over ¾ in. in thickness, a deduction from the percentage of elongation specified in Section 5 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above ¾ in., to a minimum of 18 per cent.

(*b*) For material ¼ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

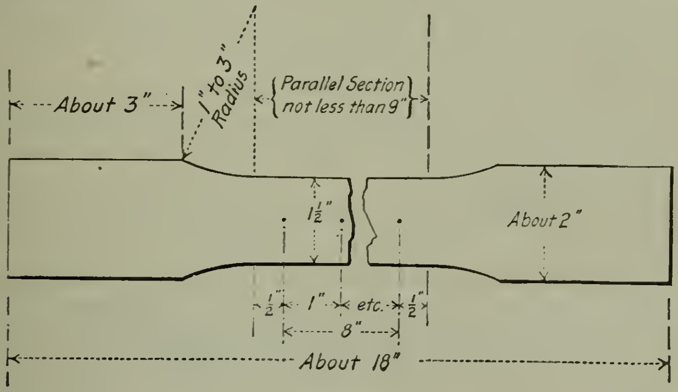

FIG. 1.

Bend Tests.

7. The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material ¾ in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over ¾ in. to and including 1¼ in. in thickness, around a pin the diameter of which is equal to 1½ times the thickness of the specimen; and for material over 1¼ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Test Specimens.

8. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*) and (*e*), shall be of the full thickness or diameter of material as rolled.

(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

(*e*) Test specimens for bars over 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2,[1] in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by ½ in. in section.

(*f*) The tension test specimen shown in Fig. 2[1] and the 1 by ½-in. bend test specimen for bars over 1½ in. in thickness or diameter shall be taken so that the axis is midway between the center and surface.

(*g*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

10. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

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[1] See Fig. 2, p. 91.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅓ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

V. FINISH.

Finish. 11. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 12. The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material. The melt number shall be legibly stamped on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection. 13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 15. Samples tested in accordance with Section 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

STANDARD SPECIFICATIONS

FOR

RIVET STEEL FOR SHIPS.

Serial Designation: A 13 – 21.

These specifications are issued under the fixed designation A 13; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1921.

A. Requirements for Rolled Bars.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition 2. The steel shall conform to the following requirements as to chemical composition:

Phosphorous	Acid	not over 0.06	per cent
	Basic	" " 0.04	"
Sulfur		" " 0.045	"

Ladle Analyses. 3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

Check Analyses. 4. Analyses may be made by the purchaser from finished bars representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 5. (*a*) The bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55 000 – 65 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent (See Section 6.)	$\frac{1\,500\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation. 6. For bars over $\frac{3}{4}$ in. in diameter, a deduction from the percentage of elongation specified in Section 5 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified diameter above $\frac{3}{4}$ in.

Bend Tests. 7. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens. 8. (*a*) Test specimens shall be of the full-diameters of bars as rolled.

(*b*) Tension and bend test specimens for rivet bars which have been cold drawn shall be normalized before testing.

Number of Tests. 9. (*a*) Two tension and two bend tests shall be made from each melt, each of which shall conform to the requirements specified; except that if bars from one melt differ $\frac{3}{8}$ in. or more in diameter, one tension and one bend test shall be made from both the greatest and the least diameters rolled.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN DIAMETER.

Permissible Variations. 10. The diameter of bars 1 in. or under in diameter shall not vary more than 0.01 in. from that specified; the diameter of bars over 1 in. to and including 2 in. in diameter shall not vary more than $\frac{1}{64}$ in. under nor more than $\frac{1}{32}$ in. over that specified.

V. FINISH.

Finish. 11. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 12. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection. 13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 15. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Rivets.

VIII. PHYSICAL PROPERTIES AND TESTS.

Test Certificate of Rolled Bars. 16. A copy of the results of tension tests of the rolled bars from which the rivets were made shall be furnished for each lot of rivets.

Tension Tests 17. If the test certificate required in Section 16 cannot be furnished, the rivets shall conform to the requirements as to tensile properties specified in Sections 5 and 6, except that the elongation shall be measured on a gage length as great as the length of the rivets tested will permit.

Bend Tests 18. The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 1, without cracking on the outside of the bent portion.

Flattening Tests. 19. The rivet head shall flatten, while hot, to a diameter $2\frac{1}{2}$ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges.

Number of Tests. 20. (*a*) When required in accordance with Section 17, one tension test shall be made from each size in each lot of rivets offered for inspection.

(*b*) Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

IX. WORKMANSHIP AND FINISH.

Workmanship. 21. The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

Finish. 22. The finished rivets shall be free from injurious defects.

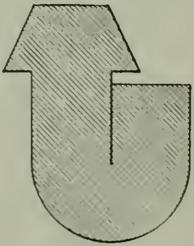

FIG. 1.

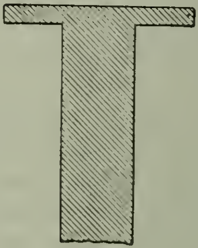

FIG. 2.

X. INSPECTION AND REJECTION.

Inspection. 23. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 24. Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL BARS FOR RAILWAY SPRINGS.

Serial Designation: A 14 – 16.

These specifications are issued under the fixed designation A 14; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1916.

Material Covered. 1. These specifications cover two grades of carbon-steel bars to be used for the manufacture of railway springs, determined by the carbon ranges specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended. The purposes for which these grades are frequently used are as follows:

Grade A, for elliptical and helical springs;
Grade B, for helical springs.

I. MANUFACTURE.

Process 2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric furnace.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

ELEMENTS CONSIDERED.	GRADE A.	GRADE B.
Carbon, per cent	0.90 – 1.10	0.95 – 1.15
Manganese, max., per cent	0.50	0.50
Phosphorus, max., per cent	0.05	0.05
Sulfur, max., per cent	0.05	0.05

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations. 6. The permissible variations in the width and thickness of the bars shall be agreed upon by the manufacturer and the purchaser.

IV. FINISH.

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

VI. INSPECTION AND REJECTION.

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL BARS FOR RAILWAY SPRINGS WITH SPECIAL SILICON REQUIREMENTS.

Serial Designation: A 68 – 18.

These specifications are issued under the fixed designation A 68; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1916; Adopted, 1918.

Material Covered.

1. These specifications cover two grades of carbon-steel bars with special silicon requirements to be used for the manufacture of railway springs, determined by the carbon ranges specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended. The purposes for which these grades are frequently used are as follows:

Grade A, for elliptical and helical springs;
Grade B, for helical springs.

I. MANUFACTURE.

Process

2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric furnace.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Elements Considered.	Grade A.	Grade B.
Carbon, per cent	0.90 – 1.10	0.95 – 1.15
Manganese, max., per cent	0.50	0.50
Phosphorus, max., per cent	0.05	0.05
Sulfur, max., per cent	0.05	0.05
Silicon, per cent	0.25 – 0.50	0.25 – 0.50

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements

specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations. 6. The permissible variations in the width and thickness of the bars shall be agreed upon by the manufacturer and the purchaser.

IV. FINISH.

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

VI. INSPECTION AND REJECTION.

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL BARS FOR VEHICLE AND AUTOMOBILE SPRINGS.

Serial Designation: A 58 – 16.

These specifications are issued under the fixed designation A 58; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1916.

Material Covered. 1. These specifications cover two grades of carbon-steel bars to be used for the manufacture of vehicle and automobile springs, determined by the carbon ranges specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended. The purposes for which these grades are frequently used are as follows:

Grade A, for vehicle springs;
Grade B, for automobile springs.

I. MANUFACTURE.

Process. 2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric furnace.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Elements Considered.		Grade A.	Grade B.
Carbon, per cent		0.85–1.05	0.90–1.05
Manganese, per cent		0.25–0.50	0.25–0.50
Phosphorus, max., per cent	Acid	0.05	0.05
	Basic	0.05	0.04
Sulfur, max., per cent		0.05	0.05

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations. 6. The permissible variations in the width and thickness of the bars shall be agreed upon by the manufacturer and the purchaser.

IV. FINISH.

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

VI. INSPECTION AND REJECTION.

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
SILICO-MANGANESE-STEEL BARS FOR AUTOMOBILE AND RAILWAY SPRINGS.

Serial Designation: A 59 – 16.

These specifications are issued under the fixed designation A 59; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916.

Material Covered. 1. These specifications cover two types of silico-manganese-steel bars to be used for the manufacture of automobile and railway springs, determined by the chemical composition specified in Section 3. The choice of the type of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended.

I. MANUFACTURE.

Process. 2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric furnace.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

ELEMENTS CONSIDERED.		TYPE A.	TYPE B.
Carbon, per cent		0.45–0.55	0.55–0.65
Manganese, per cent		0.60–0.80	0.50–0.70
Phosphorus, max., per cent	Acid	0.05	0.05
	Basic	0.045	0.045
Sulfur, max., per cent		0.045	0.045
Silicon, per cent		1.80–2.10	1.50–1.80

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations. 6. The permissible variations in the width and thickness of the bars shall be agreed upon by the manufacturer and the purchaser.

IV. FINISH.

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

VI. INSPECTION AND REJECTION.

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CHROME-VANADIUM-STEEL BARS FOR AUTOMOBILE AND RAILWAY SPRINGS.

Serial Designation: A 60 – 16.

These specifications are issued under the fixed designation A 60; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916.

Material Covered. 1. These specifications cover two grades of chrome-vanadium-steel bars to be used for the manufacture of automobile and railway springs, determined by the chemical composition specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended.

I. MANUFACTURE.

Process. 2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric furnace.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Elements Considered.		Grade A.	Grade B.
Carbon, per cent		0.45–0.55	0.55–0.65
Manganese, per cent		0.50–0.80	0.60–0.90
Phosphorus, max., per cent	Acid	0.05	0.05
	Basic	0.04	0.04
Sulfur, max., per cent		0.05	0.05
Chromium, per cent		0.80–1.10	0.80–1.10
Vanadium, min., per cent		0.15	0.15

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations. 6. The permissible variations in the width and thickness of the bars shall be agreed upon by the manufacturer and the purchaser.

IV. FINISH.

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

VI. INSPECTION AND REJECTION.

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications., All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
HELICAL STEEL SPRINGS FOR RAILWAYS.

Serial Designation: A 61 – 16.

These specifications are issued under the fixed designation A 61; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916.

Material Covered. 1. These specifications cover all helical steel springs for suspension, draft and buffer purposes for locomotives, tenders and cars.

Basis of Purchase. 2. (*a*) The springs shall be made of carbon-steel bars conforming to the requirements of the Standard Specifications for Carbon-Steel Bars for Railway Springs (Serial Designation: A 14) of the American Society for Testing Materials, unless otherwise specified.

(*b*) If carbon-steel bars with special silicon requirements or alloy-steel bars are specified, the manufacturer and the purchaser shall agree upon the type and grade of the bars to be used; in which case the bars shall conform, for the respective types, to the Standard Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (Serial Designation: A 68), the Standard Specifications for Silico-Manganese-Steel Bars for Automobile and Railway Springs (Serial Designation: A 59), or the Standard Specifications for Chrome-Vanadium-Steel Bars for Automobile and Railway Springs (Serial Designation: A 60), of the American Society for Testing Materials.

(*c*) Drillings for chemical analysis shall be taken from pieces sheared from the bars during the process of manufacture, and not from a finished spring, unless otherwise agreed upon.

I. CHEMICAL PROPERTIES AND TESTS.

Check Analyses 3. (*a*) An analysis may be made by the purchaser from a sample representing each size of spring steel involved. The chemical composition thus determined shall conform to the reqirements specified in Section 2 (*a*) or (*b*).

(*b*) Drillings for analysis shall be taken from the unworked portion of the bars and shall represent the full cross-section after rejecting any decarburized material.

(*c*) In case of dispute, check and arbitration analyses of carbon steel shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, the carbon being determined by the "direct-combustion" method; and of alloy steel, in accordance with the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.

II. WORKMANSHIP.

Inspection. 4. The purchaser or his representative may examine all springs in each lot for workmanship and general dimensions.

Workmanship. 5. (*a*) The springs shall be submitted for inspection complete in the condition required by the drawings, and shall conform to these drawings with the permissible variations specified in this Section and Section 7.

(*b*) The springs shall be of uniform pitch with ends tapered to give a reasonably square, firm bearing. The points of bars shall not protrude beyond the outside diameter of the springs.

(*c*) The outside dimensions of the springs, excepting the height, shall not vary more than $\frac{1}{16}$ in. from those specified.

III. PHYSICAL PROPERTIES AND TESTS.

Number of Tests. 6. (*a*) From each lot of springs which has met the requirements of Section 5, the purchaser or his representative may select for physical tests at least 10 per cent, to be tested in accordance with the requirements of Section 7 and the appendix.

(*b*) If any of the springs representing a lot fail to meet the requirements as to physical properties specified in Section 7, but at least half of the springs representing a lot do meet these requirements, each spring of the lot shall be tested and those which meet the requirements shall be accepted. If more than half of the springs representing a lot fail to meet the requirements specified in Section 7, the lot represented will be rejected.

7. The properties specified in Paragraphs (*a*), (*b*), (*c*) and (*d*), modified if necessary to conform to the requirements of the appendix, shall be determined in the order specified. The

spring shall not be rapped or otherwise disturbed during the test.

(*a*) *Solid Height.*—The solid height is the perpendicular distance between the plates of the testing machine when the spring is compressed solid with a test load at least $1\frac{1}{4}$ times that necessary to bring all the coils in contact. The solid height shall not vary more than $\frac{1}{8}$ in. from that specified.

Physical Tests.

(*b*) *Free Height.*—The free height is the height of the spring when the load specified in Paragraph (*a*) has been released, and is determined by placing a straight edge across the top of the spring and measuring the perpendicular distance from the plate on which the spring stands to the straight edge, at the approximate center of the spring. The free height shall not vary more than $\frac{1}{8}$ in. from that specified.

(*c*) *Loaded Height.*—The loaded height is the distance between the plates of the testing machine when the specified working load is applied. The loaded height shall not vary more than $\frac{1}{8}$ in. over nor more than $\frac{1}{16}$ in. under that specified.

(*d*) *Permanent Set.*—The permanent set is the difference, if any, between the free height and the height (measured at the same point and in a similar manner) after the spring has been compressed solid three times in rapid succession with the test load specified in Paragraph (*a*). The permanent set shall not exceed $\frac{1}{32}$ in.

IV. MARKING.

Marking.

8. (*a*) The name or brand of the manufacturer, the year and month of manufacture, and if specified, the purchaser's class number, shall be legibly stamped on each spring at a place not detrimental to the life or service of the spring.

(*b*) Any stamping by the inspector shall be so placed as not to be detrimental to the life or service of the spring.

V. INSPECTION AND REJECTION.

Inspection.

9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the springs ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the springs are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be

so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

10. Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples.

Rehearing.

11. Samples tested in accordance with Section 3, which represent rejected springs, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Reworking.

12. Any springs which fail to meet the requirements as to dimensions or physical tests may be again submitted after being reworked.

APPENDIX.

Test Fiber Stress.

13. (*a*) The properties and methods of testing specified in Section 7 have been established for carbon-steel springs on the assumption that the maximum fiber stress under test shall not exceed 90,000 lb. per sq. in.[1]

(*b*) For alloy-steel springs practice has not been sufficiently well established to enable definite fiber stresses to be given. Unless otherwise agreed upon by the manufacturer and the purchaser, alloy-steel springs shall be tested under the conditions as to fiber stress specified for carbon-steel springs.

Relation Between Fiber Stress and Load.

14. To find the maximum load under which the conditions of Section 13 (*a*) are fulfilled, the following formula shall be used:

$$P = \frac{3.1416\, S\, d^3}{8\, M} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where P = the load in pounds; S = the stress of the most strained fiber in pounds per square inch; d = the diameter of the bar in inches; and M = the mean diameter of the helix in inches; this is found by subtracting the diameter or thickness of the bar from the outside diameter of the spring.

Test of Springs not in Accordance with Preceding Rules.

15. If it is desired to purchase under these specifications springs in which the maximum fiber stress exceeds that specified in Section 13 (*a*), the tests shall be made as specified in Section 7 except that the maximum test load to be applied in determining the properties specified in Sections 7 (*a*) and (*d*) shall not be sufficient to compress the spring solid, but shall be the load which corresponds to a fiber stress of 90,000 lb. per sq. in., as determined by Eq. 1.

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[1] This stress is given solely as a limiting stress not to be exceeded in testing by the methods covered by the specifications. It is not intended as a guide in the design of springs, as the proper working fiber stress will depend on the class and design of the spring and on the service for which it is intended.

TABLE I.—TEST LOADS FOR HELICAL SPRINGS, IN POUNDS, WHICH WILL CORRESPOND TO A MAXIMUM FIBER STRESS OF 90,000 LB. PER SQ. IN.

Outside Diameter of Spring, in.	Diameter of Bar, in.																					Outside Diameter of Spring, in.
	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{9}{16}$	
2	640	1 145	1 895	2 950	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
2¼	555	995	1 630	2 530	3 730	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2¼
2½	495	880	1 310	2 215	3 250	4 620	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2½
2¾	445	785	1 180	1 970	2 880	4 080	5 580	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2¾
3	400	710	1 070	1 770	2 580	3 650	4 980	6 630	....	....	....	....	....	....	....	....	....	....	....	....	....	3
3¼	....	650	985	1 610	2 340	3 300	4 500	5 970	7 800	....	....	....	....	....	....	....	....	....	....	....	....	3¼
3½	....	....	910	1 475	2 140	3 010	4 100	5 420	7 080	9 020	....	....	....	....	....	....	....	....	....	....	....	3½
3¾	....	....	....	1 360	1 970	2 770	3 750	4 970	6 450	8 250	10 390	....	....	....	....	....	....	....	....	....	....	3¾
4	....	....	....	1 265	1 830	2 560	3 470	4 600	5 950	7 590	9 550	11 800	....	....	....	....	....	....	....	....	....	4
4¼	....	....	....	....	1 710	2 390	3 230	4 260	5 540	7 030	8 830	10 880	13 270	....	....	....	....	....	....	....	....	4¼
4½	....	....	....	....	1 600	2 230	3 020	3 980	5 150	6 550	8 200	10 100	12 350	14 900	....	....	....	....	....	....	....	4½
4¾	....	....	....	....	....	2 100	2 830	3 730	4 830	6 120	7 680	9 450	11 500	13 850	16 700	....	....	....	....	....	....	4¾
5	....	....	....	....	....	1 980	2 670	3 510	4 540	5 750	7 200	8 850	10 750	12 950	15 600	18 500	....	....	....	....	....	5
5¼	....	....	....	....	....	....	2 520	3 310	4 290	5 410	6 780	8 330	10 120	12 150	14 650	17 300	20 200	....	....	....	....	5¼
5½	....	....	....	....	....	....	2 390	3 140	4 050	5 130	6 400	7 880	9 580	11 500	13 800	16 300	19 100	22 700	....	....	....	5½
5¾	....	....	....	....	....	....	....	2 980	3 850	4 870	6 070	7 450	9 050	10 850	13 050	15 400	18 000	21 400	24 000	....	....	5¾
6	....	....	....	....	....	....	....	2 840	3 660	4 630	5 770	7 080	8 600	10 300	12 350	14 600	17 000	20 300	23 200	26 600	3 0400	6
6¼	....	....	....	....	....	....	....	....	3 500	4 410	5 500	6 740	8 220	9 800	11 750	13 850	16 450	19 300	21 500	25 200	2 8800	6¼
6½	....	....	....	....	....	....	....	....	3 340	4 220	5 250	6 440	7 850	9 350	11 200	13 200	15 400	18 300	20 500	24 000	2 7400	6½
6¾	....	....	....	....	....	....	....	....	....	4 040	5 030	6 150	7 500	8 950	10 700	12 600	14 700	17 500	19 300	22 800	2 6100	6¾
7	....	....	....	....	....	....	....	....	....	3 870	4 820	5 900	7 180	8 550	10 200	12 050	14 000	18 700	18 000	21 800	24 800	7
7½	....	....	....	....	....	....	....	....	....	....	4 450	5 450	6 620	7 880	9 450	11 100	12 850	15 300	17 100	19 800	22 800	7½
8	....	....	....	....	....	....	....	....	....	....	....	....	6 150	7 300	8 730	10 250	11 900	14 150	15 800	18 400	21 000	8
8½	....	....	....	....	....	....	....	....	....	....	....	....	5 730	6 800	8 150	9 550	11 100	13 100	14 700	17 100	19 500	8½
9	....	....	....	....	....	....	....	....	....	....	....	....	....	6 380	7 620	8 950	10 350	12 250	13 700	15 900	18 200	9
9½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7 150	8 400	9 730	11 550	12 800	14 900	17 000	9½
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7 920	9 180	10 850	12 000	14 100	16 000	10
10½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8 700	10 300	11 400	13 300	15 100	10½
11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	9750	10 850	12 600	14 300	11
11½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10 300	12 000	13 600	11½
12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	11 400	12 900	12

TABLE TO FACILITATE CALCULATIONS.

16. Table I is arranged to facilitate the calculations necessary to determine whether a spring can be tested in accordance with the specifications without exceeding the stress given in Section 13 (*a*). The table shows the loads at which springs of various sizes are stressed to 90,000 lb. per sq. in. These are the test loads to be used for springs tested in accordance with Section 15. In testing in accordance with Section 7 (*a*) the load given in Table I for the given size of spring shall not be exceeded, unless with this load the spring is compressed solid.

STANDARD SPECIFICATIONS
FOR
ELLIPTICAL STEEL SPRINGS FOR RAILWAYS.

Serial Designation: A 62 – 16.

These specifications are issued under the fixed designation A 62; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916.

Material Covered

1. These specifications cover all elliptic steel springs for suspension, draft and buffer purposes for locomotives, tenders and cars.

Basis of Purchase

2. (*a*) The springs shall be made of carbon-steel bars conforming to the requirements of the Standard Specifications for Carbon-Steel Bars for Railway Springs (Serial Designation: A 14) of the American Society for Testing Materials, unless otherwise specified.

(*b*) If carbon-steel bars with special silicon requirements or alloy-steel bars are specified, the manufacturer and the purchaser shall agree upon the type and grade of the bars to be used; in which case the bars shall conform, for the respective types, to the Standard Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (Serial Designation: A 68), the Standard Specifications for Silico-Manganese-Steel Bars for Automobile and Railway Springs (Serial Designation: A 59), or the Standard Specifications for Chrome-Vanadium-Steel Bars for Automobile and Railway Springs (Serial Designation: A 60), of the American Society for Testing Materials.

(*c*) The bands of the springs shall be made of wrought iron conforming to the requirements of the Standard Specifications for Refined Wrought-Iron Bars (Serial Designation: A 41) of the American Society for Testing Materials; or if agreed upon, they may be made of "dead-soft" open-hearth steel, the carbon content of which shall not exceed 0.15 per cent. Bands of special design, subject to agreement between the manufacturer and the purchaser, may be made of steel castings conforming to the requirements of the Standard Specifications for Steel Castings, Class B, Soft Grade (Serial Designation: A 27), of the American Society for Testing Materials.

(*d*) Drillings for chemical analysis shall be taken from pieces sheared from the bars during the process of manufacture, and not from a finished spring, unless otherwise agreed upon.

(*e*) In determining the loaded height and loaded length of the springs, the "compression" method of Section 7 shall be used, unless the "release" method of Section 8 is specified.

I. CHEMICAL PROPERTIES AND TESTS.

Check Analyses. 3. (*a*) An analysis may be made by the purchaser from a sample representing each size of spring steel involved. The chemical composition thus determined shall conform to the requirements specified in Section 2 (*a*) or (*b*).

(*b*) Drillings for analysis shall be taken from the unworked portion of the bars and shall represent the full cross-section after rejecting any decarburized material.

(*c*) In case of dispute, check and arbitration analyses of carbon steel shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, the carbon being determined by the "direct-combustion" method; and of alloy steel, in accordance with the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.

II. WORKMANSHIP.

Inspection. 4. The purchaser or his representative may examine all springs in each lot for workmanship and general dimensions.

Workmanship. 5. (*a*) The springs shall be submitted for inspection complete in the condition required by the drawings, and shall conform to these drawings with the permissible variations specified in this Section and Sections 7 or 8. Dimensions which affect the contour only and do not affect the interchange or service of the springs need only be approximated.

(*b*) The springs shall have the leaves properly graduated in length, properly bent, and fitted to reasonably true circular arcs.

(*c*) The bands of the springs shall not vary from the specified dimensions more than $\frac{1}{16}$ in. in width and $\frac{1}{32}$ in. in thickness of straps, nor more than $\frac{1}{8}$ in. in width across the spring.

III. PHYSICAL PROPERTIES AND TESTS.

Number of Tests.

6. (*a*) From each lot of springs which has met the requirements of Section 5, the purchaser or his representative may select for physical tests at least 25 per cent, to be tested in accordance with the "compression" method of Section 7—or if specified, in accordance with the "release" method of Section 8—and the appendix.

(*b*) If any of the springs representing a lot fail to meet the requirements as to physical properties specified in Section 7 or Section 8 as required, but at least half of the springs representing a lot do meet these requirements, each spring of the lot shall be tested and those which meet the requirements shall be accepted. If more than half of the springs representing a lot fail to meet the requirements specified in Section 7 or Section 8 as required, the lot represented will be rejected.

Physical Tests: Compression Method.

7. When the "compression" method is to be used, the properties specified in Paragraphs (*a*), (*b*) and (*c*), modified if necessary to conform to the requirements of the appendix, shall be determined, in the order specified. The spring shall not be rapped or otherwise disturbed during the test. The ends of half-elliptic springs shall be supported on roller or swing bearings.

(*a*) *Free Height.*—The free height is the height of the spring after a test load of 1½ times the specified working load has been applied and fully released.

(*b*) *Loaded Height and Loaded Length.*—The loaded height and loaded length are respectively the height and length when the specified working load is applied. The load shall be applied gradually and in such a way that the specified working load shall not be exceeded. If it is exceeded, the load shall be released to not more than one-half the specified working load and then increased to the specified working load. The loaded height shall not be less, but may be ⅜ in. more than that specified. The loaded length shall not vary more than ¼ in. from that specified.

(*c*) *Permanent Set.*—The permanent set is the difference, if any, between the free height and the height after the test load of 1½ times the specified working load has again been applied and fully released. The following two requirements shall be met:

(1) The permanent set shall not exceed $\frac{1}{32}$ in.;

(2) If there is any permanent set not exceeding $\frac{1}{32}$ in. the difference between the free height and the height after

the test load of 1½ times the specified working load has been applied and fully released two additional times, shall not be greater than the permanent set first measured.

Physical Tests: Release Method.

8. When the "release" method is specified, the properties specified in Paragraphs (*a*), (*b*) and (*c*), modified if necessary to conform to the requirements of the appendix, shall be determined in the order specified. The spring shall not be rapped or otherwise disturbed during the test. The ends of half-elliptic springs shall be supported on roller or swing bearings.

(*a*) *Free Height.*—The free height is the height of the spring after a test load of 1½ times the specified working load has been applied and fully released.

(*b*) *Loaded Height and Loaded Length.*—The loaded height and loaded length are respectively the height and length when a test load of 1½ times the specified working load has been applied and is slowly released to the specified working load. If released to less than the specified working load, the load shall again be raised to 1½ times the specified working load and then released to the specified working load. The loaded height shall not be more, but may be ⅜ in. less than that specified. The loaded length shall not vary more than ¼ in. from that specified.

(*c*) *Permanent Set.*—The permanent set is the difference, if any, between the free height and the height after the test load of 1½ times the specified working load has again been applied and fully released. The following two requirements shall be met:

(1) The permanent set shall not exceed $\frac{1}{32}$ in.;

(2) If there is any permanent set not exceeding $\frac{1}{32}$ in., the difference between the free height and the height after the test load of 1½ times the specified working load has been applied and fully released two additional times, shall not be greater than the permanent set first measured.

IV. MARKING.

Marking.

9. (*a*) The name or brand of the manufacturer, the year and month of manufacture, and if specified, the purchaser's class number, shall be legibly stamped on each spring at a place not detrimental to the life or service of the spring.

(*b*) Any stamping by the inspector shall be so placed as not to be detrimental to the life or service of the spring.

V. INSPECTION AND REJECTION.

Inspection.

10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser

is being performed, to all parts of the manufacturer's works which concern the manufacture of the springs ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the springs are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manfacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples.

Rehearing. 12. Samples tested in accordance with Section 3, which represent rejected springs, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Reworking. 13. Any springs which fail to meet the requirements as to dimensions or physical tests may be again submitted after being reworked.

APPENDIX.

TEST FIBER STRESS.

14. (*a*) The properties and methods of testing specified in Sections 7 and 8, have been established for carbon-steel springs on the assumption that the maximum fiber stress under test shall not exceed 127,500 lb. per sq. in.[1]

(*b*) For alloy-steel springs practice has not been sufficiently well established to enable definite fiber stresses to be given. Unless otherwise agreed upon by the manufacturer and the purchaser, alloy-steel springs shall be tested under the conditions as to fiber stress specified for carbon-steel springs.

RELATION BETWEEN FIBER STRESS AND LOAD.

15. To find the maximum loads under which the conditions of Section 14 (*a*) are fulfilled, the following formula shall be used:

$$P = \frac{2Snbh^2}{3L} \qquad (1)$$

where P = the load in pounds; S = the stress of the most strained fiber in pounds per square inch; n = the number of plates in half-elliptic springs, or half the number of plates in full-elliptic springs; b = the width of each plate in inches; h = the thickness of each plate in inches; and L = the distance between supports, in inches, when the spring is loaded.

TEST OF SPRINGS NOT IN ACCORDANCE WITH PRECEDING RULES.

16. If it is desired to purchase under these specifications springs in which the maximum fiber stress exceeds that specified in Section 14 (*a*), the tests shall be made as specified in Sections 7 or 8 except that the test load to be applied shall not be 1½ times the specified working load, but shall be the load which corresponds to a fiber stress of 127,500 lb. per sq. in., as determined by Eq. 1.

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[1] This stress is given solely as a limiting stress not to be exceeded in testing by the methods covered by the specifications. It is not intended as a guide in the design of springs, as the proper working fiber stress will depend on the class and design of the spring and on the service for which it is intended.

TESTS OF SPRINGS FOR WHICH NO WORKING LOAD IS SPECIFIED

17. If springs are ordered to free height and length only, and no working load and no loaded dimensions are specified, the tests specified in Sections 7 or 8 shall be made, using instead of the "specified working load" the load which corresponds to a fiber stress of 75,000 lb. per sq. in., as determined by Eq. 1.

TABLE I.—TEST LOADS FOR ELLIPTICAL SPRINGS, IN POUNDS PER INCH OF EFFECTIVE WIDTH, WHICH WILL CORRESPOND TO A MAXIMUM FIBER STRESS OF 127,500 LB. PER SQ. IN.

Length of Spring, in.	Thickness of Plate, in.						
	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
20	1 0	265	...	...	...	...	...
22	136	241	377	...	...	...	...
24	125	221	345	497	...	...	...
26	115	204	319	460	625	...	...
28	107	190	296	427	581	760	...
30	100	177	277	398	543	707	896
32	..	166	259	374	509	665	840
34	...	156	244	351	479	625	791
36	..	148	230	332	452	590	748
38	...	140	218	314	429	560	708
40	...	133	208	298	407	531	673
42	...	126	198	284	388	506	640
44	...	..	189	272	370	483	612
46	...	...	180	260	354	462	585
48	...	...	...	249	339	443	561
50	...	...	...	239	325	425	538
52	...	...	...	...	313	409	518
54	...	...	...	...	302	394	499
56	...	...	...	...	...	380	481
58	...	...	...	...	...	366	465
60	...	...	...	...	...	354	450

TABLE TO FACILITATE CALCULATIONS.

18. Table I is arranged to facilitate the calculations necessary to determine whether a spring can be tested in accordance with the specifications without exceeding the stress given in Section 14 (*a*). The table shows, for various lengths and for various thicknesses of plate, the loads per inch of effective width of spring corresponding to a fiber stress of 127,500 lb. per sq. in. These are the maximum allowable test loads, and shall not be exceeded in any tests.

The loads are given per inch of effective width of spring. The effective width of spring is understood to mean the width of the individual plate multiplied by the number of plates as defined in Section 15. Consequently the total load in pounds for any spring is found by multiplying the value from Table I by the product of the width of plate into the number of plates.

STANDARD SPECIFICATIONS
FOR
ELLIPTICAL STEEL SPRINGS FOR AUTOMOBILES.

Serial Designation: A 69 – 18.

These specifications are issued under the fixed designation A 69; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1916; ADOPTED, 1918.

Material Covered. 1. These specifications cover all elliptic steel springs for automobiles.

Basis of Purchase. 2. (*a*) The manufacturer and the purchaser shall agree on the type and grade of steel bars to be used.

(*b*) If carbon-steel bars, silico-manganese-steel bars or chrome-vanadium-steel bars are specified, the bars shall conform, respectively, to the Standard Specifications for Carbon-Steel Bars for Vehicle and Automobile Springs (Serial Designation: A 58), the Standard Specifications for Silico-Manganese-Steel Bars for Automobile and Railway Springs (Serial Designation: A 59), or the Standard Specifications for Chrome-Vanadium-Steel Bars for Automobile and Railway Springs (Serial Designation: A 60), of the American Society for Testing Materials.

(*c*) Drillings for chemical analysis shall be taken from pieces sheared from the bars during the process of manufacture, and not from a finished spring, unless otherwise agreed upon.

I. CHEMICAL PROPERTIES AND TESTS.

Check Analyses. 3. (*a*) An analysis may be made by the purchaser from a sample representing each size of spring steel involved. The chemical composition thus determined shall conform to the requirements of Section 2 (*b*).

(*b*) Drillings for analysis shall be taken from the unworked portion of the bars and shall represent the full cross-section after rejecting any decarburized material.

(*c*) In case of dispute, check and arbitration analyses of carbon steel shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial

Designation: A 33) of the American Society for Testing Materials, the carbon being determined by the "direct-combustion" method; and of alloy steel, in accordance with the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.

II. WORKMANSHIP.

Inspection. 4. The purchaser or his representative may examine all springs in each lot for workmanship and general dimensions.

Workmanship. 5. (*a*) The springs shall be submitted for inspection complete in the condition required by the drawings, and shall conform to these drawings with the permissible variations specified in this Section and Section 8. Dimensions which affect the contour only and do not affect the interchange or service of the spring need only be approximated.

(*b*) The springs shall have the plates properly graduated in length, properly bent, and fitted reasonably true to the curves specified.

III. PHYSICAL PROPERTIES AND TESTS.

Number of Tests. 6. All of the springs may be tested.

Methods of Testing. 7. (*a*) Full-elliptic springs shall be tested in the upright position. One-quarter-elliptic, half-elliptic, three-quarter-elliptic, and cantilever springs shall be tested in the inverted position, and shall be so supported as to give free lateral movement on compression while remaining in position selected for test. Methods of supporting and measuring the various types of springs are illustrated in Figs. 1 to 7, inclusive.

(*b*) The anvil or pressure block of the testing machine shall be of the form shown in Fig. 8.

(*c*) Unless otherwise specified, all measurements of height are to be made as follows: in half-elliptic springs (Figs. 1 and 2), between the surfaces of the pressure block and a line joining the centers of the eyes (or through the points of support where there are no eyes); in full and three-quarter-elliptic springs (Figs. 3 and 4), between the surfaces of the upper and lower pressure blocks; in one-quarter-elliptic springs (Figs. 5 and 6), between the center of the eye (or point of support where there is no eye) and the supporting pad of the spring, measured at right angles to the surface of the latter; and in half-elliptic cantilever springs (Fig. 7), between the center of the floating eye and a horizontal plane passing through the lower surface of the spring (in inverted position) at the center bolt.

(*d*) In conducting tests, all measurements of height shall be taken to at least the nearest $\frac{1}{64}$ in. All readings of load shall be taken to at least the nearest 5 lb.

(*e*) *Maximum Test Load.*—The maximum test load required in Section 8 shall be twice the specified normal load, unless such a test load produces a deflection greater than the maximum deflection possible under the car. In the latter case, the maximum test load used shall be the load producing the maximum deflection possible under the car.

(*f*) *Application of Load.*—The application of the loads under which the height is to be measured as specified in Section 8 shall be made gradually and in such a way that the required load shall not be exceeded. If it is exceeded, the load shall be released to not more than one-half the required load and then increased to the required load under which the height is to be measured. The spring shall not be rapped or otherwise disturbed during the test.

Physical Tests.

8. The physical properties of the springs shall be determined as follows:[1]

(*a*) *Loaded Height.*—The loaded height is the height when the specified normal load is applied after the maximum test load as defined in Section 7 (*e*) has been applied and fully released three times. The loaded height in the case of pleasure cars, unless otherwise specified, shall not be less, but may be $\frac{1}{4}$ in. and $\frac{3}{8}$ in. more than that specified for front and rear springs, respectively.

(*b*) *Permanent Set.*—The permanent set is the difference, if any, between two successive measurements of the height under a load equal to 75 per cent of the specified normal load. This load shall be applied for the first time after the maximum test load has been applied and fully released three times, and for the second time after the maximum test load has been applied again and fully released. The following two requirements shall be met:

(1) The permanent set shall not exceed $\frac{1}{16}$ in.;

(2) If there is any permanent set not exceeding $\frac{1}{16}$ in., the maximum test load shall be applied and fully released two additional times and a load equal to 75 per cent of the specified normal load applied a third time. The height under this third application shall not be less than that measured under the second application.

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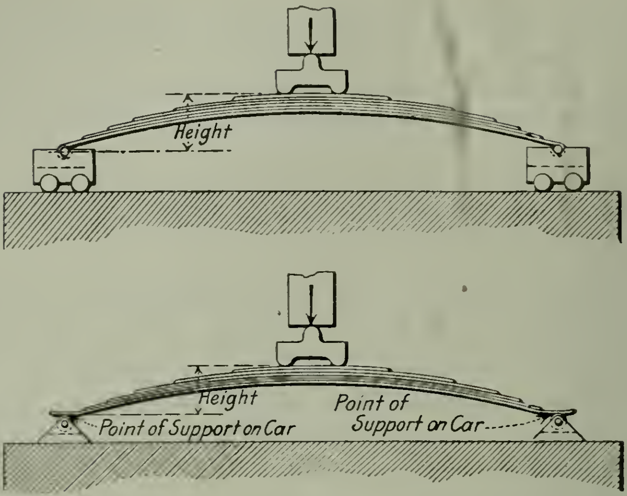
[1] See Section 14, "Appendix," for a convenient routine of tests.



FIGS. 1 AND 2.—Half-Elliptic Spring Compression Test Support.

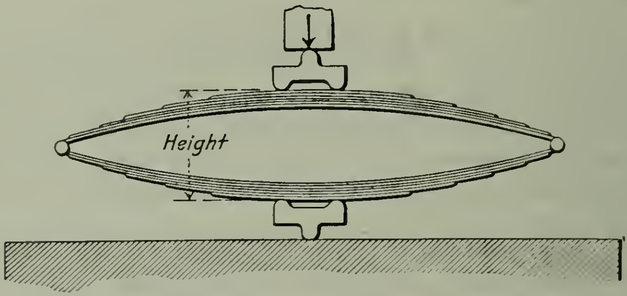


FIG. 3.—Full-Elliptic Spring Compression Test Support.

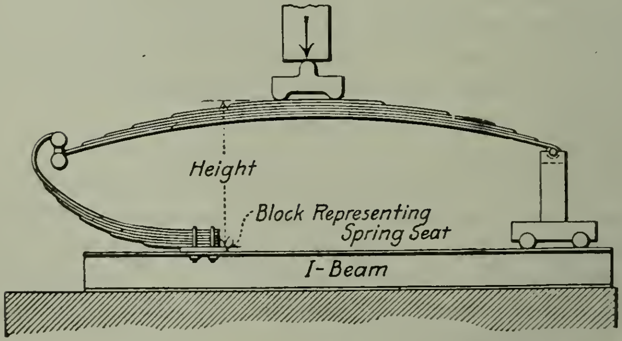
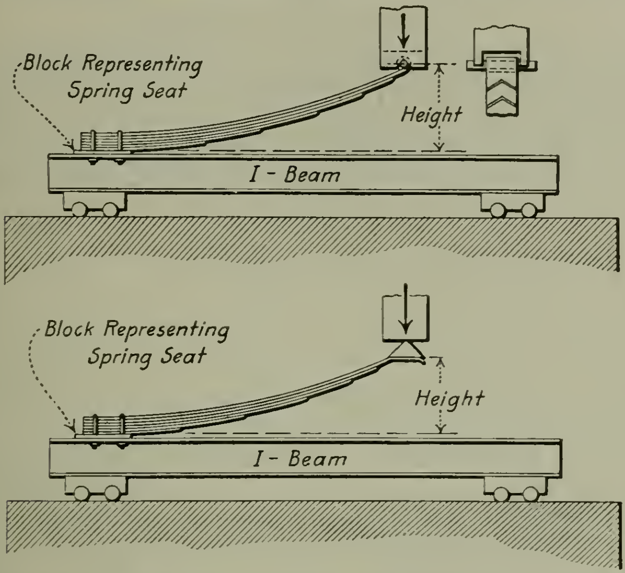


FIG. 4.—Three-Quarter-Elliptic Spring Compression Test Support.

(*c*) *Flexibility.*—The flexibility, when specified, shall be expressed in pounds per inch of deflection. It shall be determined by measuring the height under 75 per cent of the specified normal load and the height under 125 per cent of that load, and dividing the difference in loads by the difference in heights.


Block Representing Spring Seat
Height
I - Beam
Block Representing Spring Seat
Height
I - Beam

Figs. 5 and 6.—One-Quarter-Elliptic Spring Compression Test Support.

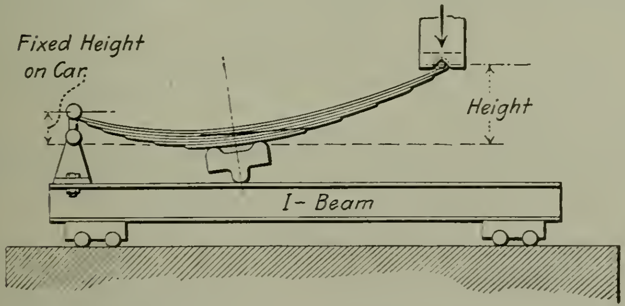


Fig. 7.—Half-Elliptic Cantilever Spring Compression Test Support.

The quotient is the flexibility in pounds per inch of deflection and shall not vary from that specified more than 5 per cent.

IV. MARKING.

9. (*a*) The name or brand of the manufacturer, the year and month of manufacture, and if specified, the purchaser's **Marking.**

class or part number, shall be legibly stamped on each spring at a place not detrimental to the life or service of the spring, on the exposed end of the compression side of a plate.

(*b*) Any stamping by the inspector shall be so placed as not to be detrimental to the life or service of the spring.

V. INSPECTION AND REJECTION.

Inspection. 10. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the springs ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the springs are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

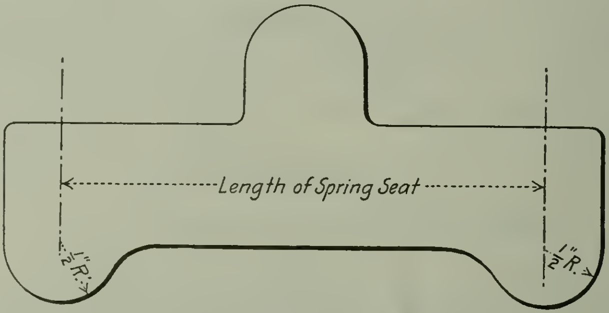


FIG. 8.—Pressure Block for Testing Springs.

Rejection. 11. Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples.

Rehearing. 12. Samples tested in accordance with Section 3, which represent rejected springs, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Reworking. 13. Any springs which fail to meet the requirements as to dimensions or physical tests may be again submitted after being remade by the manufacturer, such remaking to consist of insertion of new plates or of annealing, reforming and retreating of old plates. No springs shall contain cold reworked plates.

APPENDIX.

Recommended Routine for Testing.

Routine for Testing.

14. The physical tests required by Section 8 for the determination of loaded height, permanent set, and flexibility, can be carried out with the least possible number of operations by using the following routine of loading and measuring:

(1) Apply the maximum test load as defined in Section 7 (*e*) and release fully. Repeat this operation twice.

(2) Apply 75 per cent of the specified normal load, and measure the height (denote by h_1). This height is the first measurement for permanent set and for flexibility.

(3) Apply the specified normal load and measure the height (denote by h_2). This is the loaded height.

(4) Apply 125 per cent of the specified normal load and measure the height (denote by h_3). This is the second measurement for flexibility.

(5) Apply the maximum test load and release fully.

(6) Apply 75 per cent of the specified normal load and measure the height (denote by h_4). This is the second measurement for permanent set. If h_4 is less than h_1 the difference is the permanent set. If the permanent set does not exceed $\frac{1}{16}$ in., the following operations are required:

(7) Apply the maximum test load and release fully. Repeat this operation once.

(8) Apply 75 per cent of the specified normal load, and measure the height (denote by h_5). This is the third measurement for permanent set.

Then:—

Loaded Height $= h_2$.

Permanent Set $= h_1 - h_4$, and springs are rejected if this is more than $\frac{1}{16}$ in. or if h_5 is less than h_4.

$$\textit{Flexibility} = \frac{\frac{1}{2} \times (\text{specified normal load})}{h_1 - h_3}$$

STANDARD SPECIFICATIONS
FOR
BILLET-STEEL CONCRETE REINFORCEMENT BARS.

Serial Designation: A 15 – 14.

These specifications are issued under the fixed designation A 15; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1913, 1914.

Material Covered.

1. (*a*) These specifications cover three classes of billet-steel concrete reinforcement bars, namely: plain, deformed, and cold-twisted.

(*b*) Plain and deformed bars are of three grades, namely: structural-steel, intermediate and hard.

Basis of Purchase.

2. (*a*) The structural-steel grade shall be used unless otherwise specified.

(*b*) If desired, cold-twisted bars may be purchased on the basis of tests of the hot-rolled bars before twisting, in which case such tests shall govern and shall conform to the requirements specified for plain bars of structural-steel grade.

I. MANUFACTURE.

Process.

3. (*a*) The steel shall be made by either or both the following processes: Bessemer or open-hearth.

(*b*) The bars shall be rolled from new billets. No rerolled material will be accepted.

Cold-twisted Bars.

4. Cold-twisted bars shall be twisted cold with one complete twist in a length not over 12 times the thickness of the bar.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

5. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Bessemer	not over 0.10 per cent
	Open-hearth	" " 0.05 "

Ladle Analyses.

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made

from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

Check Analyses.

7. Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt, or lot of ten tons, of Bessemer steel. The phosphorus content thus determined shall not exceed that specified in Section 5 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

8. (*a*) The bars shall conform to the following requirements as to tensile properties:

TENSILE PROPERTIES.

Properties Considered.	Plain Bars.			Deformed Bars.			Cold-twisted Bars.
	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	
Tensile strength, lb. per sq. in..........	55 000 to 70 000	70 000 to 85 000	80 000 min.	55 000 to 70 000	70 000 to 85 000	80 000 min.	Recorded only.
Yield point, min., lb. per sq. in..........	33 000	40 000	50 000	33 000	40 000	50 000	55 000
Elongation in 8 in., min., per cent......	$\frac{1\,400\,000}{\text{Tens. str.}}$[a]	$\frac{1\,300\,000}{\text{Tens. str.}}$[a]	$\frac{1\,200\,000}{\text{Tens. str.}}$[a]	$\frac{1\,250\,000}{\text{Tens. str.}}$[a]	$\frac{1\,125\,000}{\text{Tens. str.}}$[a]	$\frac{1\,000\,000}{\text{Tens. str.}}$[a]	5

[a] See Section 9.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

9. (*a*) For plain and deformed bars over ¾ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 8 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness or diameter above ¾ in.

(*b*) For plain and deformed bars under $\frac{7}{16}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 8 (*a*) of 0.5 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness or diameter below $\frac{7}{16}$ in.

Bend Tests

10. The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

BEND-TEST REQUIREMENTS.

Thickness or Diameter of Bar.	Plain Bars.			Deformed Bars.			Cold-twisted Bars.
	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	
Under $\frac{3}{4}$ in..........	180 deg. d = t	180 deg. d = 2t	180 deg. d = 3t	180 deg. d = t	180 deg. d = 3t	180 deg. d = 4t	180 deg d = 2t
$\frac{3}{4}$ in. or over.........	180 deg. d = t	90 deg. d = 2t	90 deg. d = 3t	180 deg. d = 2t	90 deg. d = 3t	90 deg. d = 4t	180 deg. d = 3t

EXPLANATORY NOTE: d = the diameter of pin about which the specimen is bent;
t = the thickness or diameter of the specimen.

Test Specimens.

11. (*a*) Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 in., if deemed necessary by the manufacturer to obtain uniform cross-section.

(*b*) Tension and bend test specimens for cold-twisted bars shall be taken from the finished bars, without further treatment; except as specified in Section 2 (*b*).

Number of Tests

12. (*a*) One tension and one bend test shall be made from each melt of open-hearth steel, and from each melt, or lot of ten tons, of Bessemer steel; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness or diameter, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT.

Permissible Variations.

13. The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

V. FINISH.

Finish.

14. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. INSPECTION AND REJECTION.

Inspection.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 7, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
RAIL-STEEL CONCRETE REINFORCEMENT BARS.

Serial Designation: A 16 – 14.

These specifications are issued under the fixed designation A 16; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1913; Revised, 1914.

Material Covered.

1. These specifications cover three classes of rail-steel concrete reinforcement bars, namely: plain, deformed, and hot-twisted.

I. MANUFACTURE.

Process.

2. The bars shall be rolled from standard section Tee rails.

Hot-twisted Bars.

3. Hot-twisted bars shall have one complete twist in a length not over 12 times the thickness of the bar.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

4. (*a*) The bars shall conform to the following minimum requirements as to tensile properties:

Properties Considered.	Plain Bars.	Deformed and Hot-twisted bars.
Tensile strength, lb. per sq. in.	80 000	80 000
Yield point, lb. per sq. in.	50 000	50 000
Elongation in 8 in., per cent[1]	$\frac{1\,200\,000}{\text{Tens. str.}}$	$\frac{1\,000\,000}{\text{Tens. str.}}$

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[1] See Section 5.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

5. (*a*) For bars over $\frac{3}{4}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 4 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness or diameter above $\frac{3}{4}$ in.

(*b*) For bars under $\frac{7}{16}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section

4 (*a*) of 0.5 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness or diameter below $\frac{7}{16}$ in.

Bend Tests. 6. The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

Thickness or Diameter of Bar.	Plain Bars.	Deformed and Hot-twisted Bars.
Under $\frac{3}{4}$ in.	180 deg. d = 3 t	180 deg. d = 4 t
$\frac{3}{4}$ in. or over	90 deg. d = 3 t	90 deg. d = 4 t

EXPLANATORY NOTE: d = the diameter of pin about which the specimen is bent;
t = the thickness or diameter of the specimen.

Test Specimens. 7. (*a*) Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 in., if deemed necessary by the manufacturer to obtain uniform cross-section.

(*b*) Tension and bend test specimens for hot-twisted bars shall be taken from the finished bars, without further treatment.

Number of Tests. 8. (*a*) One tension and one bend test shall be made from each lot of ten tons or less of each size of bar rolled from rails varying not more than 10 lb. per yd. in nominal weight.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 4 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

III. PERMISSIBLE VARIATIONS IN WEIGHT.

Permissible Variations. 9. The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

IV. FINISH.

Finish. 10. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

V. INSPECTION AND REJECTION.

Inspection. 11. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 12. Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS

FOR

CARBON-STEEL AND ALLOY-STEEL BLOOMS, BILLETS AND SLABS FOR FORGINGS.

Serial Designation: A 17 – 21.

These specifications are issued under the fixed designation A 17; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1913; Revised, 1918, 1921.

Definition of Terms.

1. The term "billet" is used in these specifications to include blooms, billets and slabs.

Material Covered.

2. (*a*) These specifications cover billets of carbon and alloy steel. Eight types of steel are covered, one type of carbon and seven types of alloy steels, classification by type being made according to the chemical composition, other than carbon.

(*b*) Each type of steel is sub-divided into grades according to the carbon content. There are eight grades of carbon steel and seven grades of each type of alloy steel.

(*c*) The billets are further divided into two classes, designated Classes I and II. Class I is the standard for all types and grades; and Class II is a special class applicable to Grades Nos. 4 to 8, inclusive, in Type A, and to Grades Nos. 14 to 17, inclusive, in all other types. Class II differs from Class I in the method of sampling for chemical analysis and in chemical requirements.

Basis of Purchase.

3. Billets shall be purchased as semi-finished rolled or forged material.

I. MANUFACTURE.

Process.

4. The steel shall be made by either or both the following processes: open-hearth or electric furnace.

Discard.

5. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Reduction from Ingot.

6. Unless otherwise specified, the billets shall be made from ingots of at least four times the cross-sectional area of the billet.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

7. The steel shall conform to the following requirements as to chemical composition for type and grade:

(*a*) *Type.*—The types of steel shall be as indicated in Table I.

(*b*) *Grade.*—The carbon ranges for the various grades shall be as follows for carbon and alloy steel:

CARBON STEEL—TYPE A.

GRADE.	CARBON, PER CENT.
1	0.05 – 0.15
2	0.15 – 0.25
3	0.20 – 0.30
4	0.25 – 0.40
5	0.30 – 0.45
6	0.35 – 0.50
7	0.40 – 0.55
8	0.45 – 0.60

ALLOY STEELS—TYPES B TO H, INCL.

GRADE.	CARBON, PER CENT.
11	0.10 – 0.20
12	0.15 – 0.25
13	0.20 – 0.30
14	0.25 – 0.38
15	0.30 – 0.43
16	0.35 – 0.50
17	0.45 – 0.60

NOTE 1. When the steel is to be used for case-hardening purposes, the manganese should be specified not to exceed 0.50 per cent. When the minimum carbon specified is 0.35 per cent or over, the manganese range may be specified 0.30 – 0.60 per cent.

NOTE 2. In selecting billets for making forgings of Classes K, L and M, as defined in the Standard Specifications for Carbon-Steel and Alloy-Steel Forgings (Serial Designation: A 18) of the American Society for Testing Materials, it is suggested that the use of steel with a relatively high carbon content will permit the use of a high draw-back temperature and thus put the steel in its best physical condition for service, shock and similar conditions.

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. (*a*) *Class I.*—For billets of Class I, an analysis may be made by the purchaser from one billet representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis shall be taken with a $\frac{3}{8}$-in. drill, parallel to the axis of the ingot as cast, at any point midway between the center and surface of the billet.

(*b*) *Class II.*—For billets of Class II, the purchaser or his representative may select one top-cut billet from which to make check analyses to represent each melt. Two sets of drillings shall be taken from the top face of this billet at points on the same diagonal of the billet. The drillings shall be taken with a ⅝-in. drill parallel to the axis of the ingot as cast. The distance from the center of the billet to the drilling points shall be respectively 15 and 80 per cent of the length of the half diagonal of the billet.

(*c*) From the drillings taken at the 80-per-cent point a complete analysis may be made. The chemical composition thus determined shall conform to the requirements specified in Section 7.

(*d*) From the drillings taken at the 15-per-cent point a carbon determination may be made. The difference between the carbon content of the drillings from the 15-per-cent point and that of the drillings from the 80-per-cent point, expressed as a percentage of the latter, shall not exceed the following values:

TABLE I.—TYPES OF STEEL.

ELEMENTS CONSIDERED.	TYPE.							
	A.	B.	C.	D.	E.	F.	G.	H
	Carbon Steel.	Nickel Steel.	Chrome-Nickel Steel.				Chrome Steel.	Chrome-Vanadium Steel.
			1.00 - 1.50 per cent Ni.	1.50 - 2.00 per cent Ni.	2.75 - 3.25 per cent Ni.	3.00 min. per cent Ni.		
Manganese, per cent...	0.50 - 0.80	0.50 - 0.80	0.50 - 0.80	0.30 - 0.60	0.45 - 0.75	0.30 - 0.60	0.30 - 0.60	0.50 - 0.80
Phosphorus, max., per cent...	0.045	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max., per cent...	0.050	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Nickel, per cent...	.....	not under 3.00	1.00 - 1.50	1.50 - 2.00	2.75 - 3.25	not under 3.00	.....	.....
Chromium, per cent...	.....	.....	0.45 - 0.75	0.90 - 1.25	0.60 - 0.95	not under 1.00	0.60 - 0.90	0.80 - 1.10
Vanadium, min., per cent...	.....	.....	.....	.....	.....	.....	.....	0.15

(1) For billets 15 in. or under in thickness, 15 per cent;

(2) For billets over 15 in. in thickness, 20 per cent.

(*e*) If in any melt the drillings taken in accordance with Paragraph (*b*) do not conform to the requirements of Paragraph (*d*), additional drillings may be taken in a similar manner after making a further top discard from the material from each ingot of at least 10 per cent of the original ingot weight. The results of this analysis shall conform to the requirements of Paragraph (*d*); otherwise, the melt represented shall be rejected.

III. WORKMANSHIP AND FINISH.

Chipping. 10. (*a*) Billets may be chipped to remove surface defects, provided that the depth of chipping does not exceed $\frac{1}{16}$ in. for each inch of dimension concerned, up to a maximum depth of $\frac{3}{4}$ in., and provided that the width of the chipping is at least four times its greatest depth; except that in the case of slabs where the width is at least twice the thickness, the depth of chipping on the wide surfaces may exceed this allowance by 50 per cent, up to a maximum depth of $\frac{3}{4}$ in.

(*b*) In special cases, particularly large alloy-steel billets where it is necessary and is not injurious, greater depth of chipping may be permitted by special agreement between the manufacturer and the purchaser.

Finish. 11. The billets shall be free from injurious defects and shall have a workmanlike finish.

IV. MARKING.

Marking 12. (*a*) The melt number shall be legibly stamped on each billet 6 in. or over in thickness, and on billets of smaller section when so specified.

(*b*) For billets of Class I, the top end of all top-cut billets 6 in. or over in thickness shall be legibly hot-stamped with the letter "T" and marked with paint.

(*c*) For billets of Class II, the top ends of the top, second, third, and following cut billets from each ingot shall be legibly hot-stamped with the letters "A", "B", "C", etc., to show the position of the billet in the ingot, and marked with paint.

V. INSPECTION AND REJECTION.

Inspection. 13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the billets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the billets are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of billets in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

14. (*a*) Unless otherwise specified, any rejections based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Billets which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

15. Samples tested in accordance with Section 13 (*b*), which represent rejected billets, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL AND ALLOY-STEEL FORGINGS.

Serial Designation: A 18 – 21.

These specifications are issued under the fixed designation A 18; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1914, 1916, 1918, 1921.

Material Covered.

1. (*a*) These specifications cover the various classes of carbon-steel and alloy-steel forgings now commonly used and not covered by other existing specifications of the American Society for Testing Materials.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for forgings which may be welded or case-hardened;

Class B, for mild-steel forgings for structural purposes, for minor ship fittings, etc.;

Class C, for mild-steel forgings for structural purposes, for ships, etc.;

Classes D, E, F, G, H and I, for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed.

Classes K, L and M, for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed, and upon the character of machining operations to be done.

I. MANUFACTURE.

Process.

2. The steel shall be made by either or both the following processes: open-hearth or electric furnace.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

4. The manufacturer and the purchaser shall agree upon forgings on which a prolongation for test purposes shall be provided.

Boring.

5. If boring is specified, the diameter of the hole shall

be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. Heat treatment, if required, shall consist of either annealing or quenching and tempering, as specified.

(*a*) The procedure to be followed in annealing shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly.

(*b*) The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

7. (*a*) The steel shall conform to the following requirements as to chemical composition:

ELEMENTS CONSIDERED.	CLASSES.				
	A.	B, C, D, E, F, G.	H, I.	K, L.	M.
Manganese, per cent....	0.30 - 0.55	0.40 - 0.80	0.40 - 0.80	....	....
Phosphorus, per cent:					
Acid................	not over 0.05	not over 0.05	not over 0.04	not over 0.05	not over 0.04
Basic...............	" " 0.05	" " 0.05	" " 0.04	" " 0.04	" " 0.04
Sulfur, per cent.........	" " 0.05	" " 0.05	" " 0.05	" " 0.05	" " 0.05
Nickel, per cent........	....	....	not under 3.00	....	....

(*b*) The composition of alloy steel, other than phosphorus and sulfur, to be used in forgings of Classes K, L and M, shall be agreed upon by the manufacturer and the purchaser.

Ladle Analyses

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese

and the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

10. (*a*) The forgings shall conform to the requirements as to tensile properties specified in Tables I, II and III.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

(*d*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*e*) Tests of forgings shall be made only after final treatment.

Tension Test Specimens.

11. (*a*) Tension test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

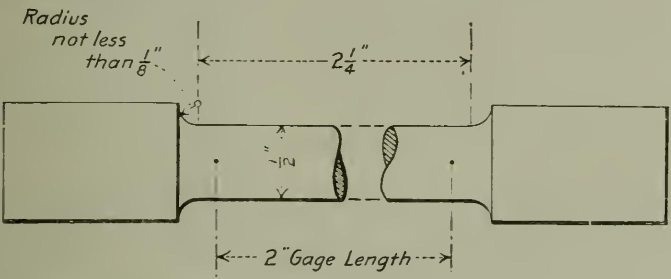
(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

12. Unless otherwise specified by the purchaser, tests shall be made as follows:

(*a*) For untreated forgings, one tension test shall be made from each melt.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*b*) For annealed forgings, one tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension test shall be made from each melt.

(*c*) For quenched and tempered forgings, one tension test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension test shall be made from each melt.

(*d*) If more than one class of forgings by size is represented in any lot, one tension test from a forging of each class by size shall be made as specified in Sections 10 and 11.

(*e*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*f*) If the percentage of elongation of any test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

TABLE I.—TENSILE PROPERTIES (CLASSES A TO F, INCLUSIVE).

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 IN.

CLASS.	SIZE. Outside Diameter or Over-all Thickness.	Tensile Strength, min. (except Class A), lb. per sq. in.	Yield Point, min., lb. per sq. in	Elongation in 2 in., min., per cent.		Reduction of Area, min., per cent.	
				Inverse Ratio.	Not under	Inverse Ratio.	Not under
A UNTREATED	All sizes........	47 000 to 60 000	0.5 tens. str.	$\frac{1\,500\,000}{\text{Tens. str.}}$	..	$\frac{2\,500\,000}{\text{Tens. str.}}$	..
B UNTREATED	Not over 12 in..	60 000	0.5 tens. str.	$\frac{1\,550\,000}{\text{Tens. str.}}$	22	$\frac{2\,400\,000}{\text{Tens. str.}}$	35
	Over 12 to 20 in., inclusive..	60 000	0.5 tens str	$\frac{1\,480\,000}{\text{Tens. str.}}$	21	$\frac{2\,220\,000}{\text{Tens. str.}}$	32
C ANNEALED	Not over 12 in..	60 000	0.5 tens. str.	$\frac{1\,700\,000}{\text{Tens. str.}}$	25	$\frac{2\,700\,000}{\text{Tens. str.}}$	38
	Over 12 to 20 in., inclusive..	60 000	0.5 tens. str.	$\frac{1\,600\,000}{\text{Tens. str.}}$	24	$\frac{2\,520\,000}{\text{Tens. str.}}$	36
D UNTREATED	Not over 8 in...	75 000	0.5 tens. str.	$\frac{1\,600\,000}{\text{Tens. str.}}$	18	$\frac{2\,200\,000}{\text{Tens. str.}}$	24
	Over 8 to 12 in., inclusive.....	75 000	0.5 tens. str.	$\frac{1\,500\,000}{\text{Tens. str.}}$	17	$\frac{2\,000\,000}{\text{Tens. str.}}$	22
	Over 12 to 20 in., inclusive..	75 000	0.5 tens. str.	$\frac{1\,400\,000}{\text{Tens. str.}}$	16	$\frac{1\,800\,000}{\text{Tens. str.}}$	20
E ANNEALED	Not over 8 in...	75 000	0.5 tens. str.	$\frac{1\,800\,000}{\text{Tens. str.}}$	20	$\frac{2\,800\,000}{\text{Tens. str.}}$	33
	Ov 8 to 12 in., inclusive.....	75 000	0.5 tens. str.	$\frac{1\,725\,000}{\text{Tens. str.}}$	19	$\frac{2\,640\,000}{\text{Tens. str.}}$	31
	Over 12 to 20 in., inclusive..	75 000	0.5 tens. str.	$\frac{1\,650\,000}{\text{Tens. str.}}$	18	$\frac{2\,400\,000}{\text{Tens. str.}}$	29
F ANNEALED	Not over 8 in...	80 000	0.5 tens. str.	$\frac{1\,800\,000}{\text{Tens. str.}}$	20	$\frac{2\,800\,000}{\text{Tens. str.}}$	32
	Over 8 to 12 in., inclusive.....	80 000	0.5 tens. str.	$\frac{1\,725\,000}{\text{Tens. str.}}$	19	$\frac{2\,640\,000}{\text{Tens. str.}}$	30
	Over 12 to 20 in., inclusive..	80 000	0.5 tens. str.	$\frac{1\,650\,000}{\text{Tens. str.}}$	18	$\frac{2\,400\,000}{\text{Tens. str.}}$	28

Retests. 13. If the results of the physical tests of any test lot of forgings do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times and retests shall be made as specified in Section 12.

TABLE II.—TENSILE PROPERTIES (CLASSES G, H, AND I).

CLASS.	SIZE.	Tensile Strength, min., lb. per sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent.		Reduction of Area, min., per cent.	
				Inverse Ratio.	Not under	Inverse Ratio.	Not under
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.							
G QUENCHED AND TEMPERED.	Up to 4 in. in outside diameter or thickness, 2-in. max. wall......	90 000	55 000	$\frac{2\ 100\ 000}{\text{Tens. str.}}$	20.5	$\frac{4\ 000\ 000}{\text{Tens. str.}}$	39
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall...........	85 000	50 000	$\frac{2\ 000\ 000}{\text{Tens. str.}}$	20.5	$\frac{3\ 800\ 000}{\text{Tens. str.}}$	39
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall...........	85 000	50 000	$\frac{1\ 900\ 000}{\text{Tens. str.}}$	19.5	$\frac{3\ 600\ 000}{\text{Tens. str.}}$	37
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall.......	82 500	48 000	$\frac{1\ 800\ 000}{\text{Tens. str.}}$	19	$\frac{3\ 400\ 000}{\text{Tens. str.}}$	36
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 IN.							
H NICKEL STEEL, ANNEALED.	Outside diameter or over-all thickness not over 12 in......	80 000	50 000	$\frac{2\ 000\ 000}{\text{Tens. str.}}$	22	$\frac{3\ 600\ 000}{\text{Tens. str.}}$	40
	Outside diameter or over-all thickness over 12 to 20 in., inclusive.........	80 000	50 000	$\frac{1\ 900\ 000}{\text{Tens. str.}}$	21	$\frac{3\ 400\ 000}{\text{Tens. str.}}$	38
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.							
I NICKEL STEEL, QUENCHED AND TEMPERED.	Up to 4 in. in outside diameter or thickness, 2-in. max. wall......	100 000	70 000	$\frac{2\ 200\ 000}{\text{Tens. str.}}$	20	$\frac{4\ 500\ 000}{\text{Tens. str.}}$	41
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall......	100 000	65 000	$\frac{2\ 100\ 000}{\text{Tens. str.}}$	20	$\frac{4\ 300\ 000}{\text{Tens. str.}}$	41
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall...........	90 000	60 000	$\frac{2\ 000\ 000}{\text{Tens. str.}}$	20	$\frac{4\ 100\ 000}{\text{Tens. str.}}$	41
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall.......	85 000	55 000	$\frac{1\ 900\ 000}{\text{Tens. str.}}$	20	$\frac{3\ 900\ 000}{\text{Tens. str.}}$	41

TABLE III.—TENSILE PROPERTIES (CLASSES K, L AND M).

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

CLASS.	SIZE.	Tensile Strength, lb. per sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent.	Reduction of Area, min., per cent.
K ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall....	95 000 – 115 000	70 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	90 000 – 110 000	65 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall......................	90 000 – 110 000	65 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall......................	90 000 – 110 000	65 000	20	50
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	85 000 – 105 000	60 000	20	50
L ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall..	105 000 – 125 000	80 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	100 000 – 120 000	75 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall......................	100 000 – 120 000	75 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall......................	100 000 – 120 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	95 000 – 115 000	70 000	18	45
		Minimum.			
M ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall.	125 000	105 000	16	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	115 000	95 000	16	45
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall......................	110 000	85 000	16	45
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall.....................	100 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	100 000	70 000	18	45

IV. WORKMANSHIP AND FINISH.

14. The forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used. **Workmanship.**

15. The forgings shall be free from injurious defects and shall have a workmanlike finish. **Finish.**

V. MARKING.

16. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks. **Marking.**

VI. INSPECTION AND REJECTION.

17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment. **Inspection.**

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 17 (*b*) shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

19. Samples tested in accordance with Section 17 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS

FOR

QUENCHED-AND-TEMPERED CARBON-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS.

Serial Designation: A 19 – 21.

These specifications are issued under the fixed designation A 19; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1914, 1916, 1918, 1921.

Material Covered.

1. When used for forgings for locomotives, these specifications cover quenched-and-tempered carbon-steel driving axles, engine and trailing-truck axles, main and side rods, straps, crank pins and piston rods.

I. MANUFACTURE.

Process.

2. The steel shall be made by either or both the following processes: open-hearth or electric furnace.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

4. For test purposes, a prolongation shall be left on each forging, unless otherwise specified by the purchaser.

Boring.

5. (*a*) Unless otherwise specified by the purchaser, all forgings over 7 in. in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring shall be done before quenching.

(*b*) If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially

uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 7. The steel shall conform to the following requirements as to chemical composition:

Carbon	First Class by Size..........	0.25 – 0.60 per cent
	Second " " "	0.35 – 0.60 "
	Third " " "	0.35 – 0.65 "
	Fourth " " "	0.35 – 0.70 "
Manganese	....	0.40 – 0.70 "
Phosphorus	....	not over 0.05 "
Sulfur	....	" " 0.05 "

Ladle Analyses. 8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses. 9. (*a*) An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

(*b*) In addition to the complete analysis specified in Paragraph (*a*), a phosphorus determination may be made by the purchaser from each broken tension test specimen. The phosphorus content thus determined shall conform to the requirement specified in Section 7.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 10. (*a*) The forgings shall conform to the minimum requirements as to tensile properties specified in Table I.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase.

TABLE I.—TENSILE PROPERTIES.

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

SIZE.	Tensile Strength, lb. per sq. in.	Elastic Limit, lb. per sq. in.	Elongation in 2 in., per cent.		Reduction of Area, per cent.	
			Inverse Ratio.	Not under	Inverse Ratio.	Not under
Up to 4 in. in outside diameter or thickness, 2-in. max. wall.....	90 000	55 000	$\frac{2\ 100\ 000}{\text{Tens. str.}}$	20.5	$\frac{4\ 000\ 000}{\text{Tens. str.}}$	39
Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall........................	85 000	50 000	$\frac{2\ 000\ 000}{\text{Tens. str.}}$	20.5	$\frac{3\ 800\ 000}{\text{Tens. str}}$	39
Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall........................	85 000	50 000	$\frac{1\ 900\ 000}{\text{Tens. str.}}$	19.5	$\frac{3\ 600\ 000}{\text{Tens. str.}}$	37
Outside diameter or thickness not over 20 in., 5 to 8-in. wall... .	82 500	48 000	$\frac{1\ 800\ 000}{\text{Tens. str.}}$	19	$\frac{3\ 400\ 000}{\text{Tens. str.}}$	36

The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*d*) Tests of forgings shall be made only after final treatment.

Bend Tests. 11. If specified by the purchaser, bend tests shall be made as follows:

(*a*) For the first and second classes by size, the test specimen shall withstand being bent cold through 180 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

(*b*) For the third and fourth classes by size, the test specimen shall withstand being bent cold through 180 deg. around a pin 1½ in. in diameter, without cracking on the outside of the bent portion.

Proof Tests.

12. Unless otherwise specified by the purchaser, all forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.[1]

Test Specimens.

13. (*a*) Tension and bend test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend test specimens shall be ½ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests.

14. (*a*) One tension and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension and, if specified, one bend test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension and, if specified, one bend test from a forging of each class by size shall be made as specified in Sections 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any tension test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than ¾ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

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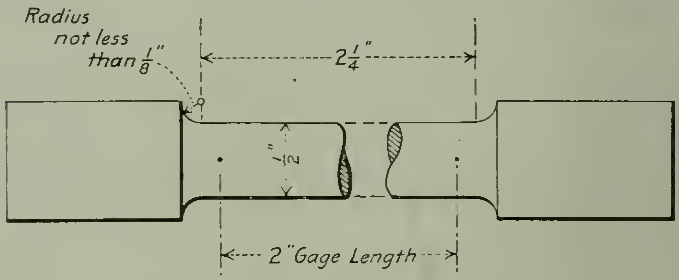
[1] For information relative to proof tests of finished forgings, see Appendix, pp. 160–161.

Retests

15. (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 14.

(*b*) If the fracture of any tension test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be retempered or requenched and tempered. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.



Note:—The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

IV. WORKMANSHIP AND FINISH.

Workmanship.

16. The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance of $\frac{1}{8}$ in. on the surface for finishing. In centering, 60-deg. centers with clearance drilled for points shall be used.

Finish.

17. The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking.

18. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION

19. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment. **Inspection.**

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 19 (*b*) shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

21. Samples tested in accordance with Section 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

APPENDIX.

As a guide in deciding on a proof test for quenched-and-tempered forgings, the following particulars regarding three established methods of testing are given.[1] These methods of proof testing are giving satisfactory results in practice.

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS.

Diameter, in.	PENNSYLVANIA RAILROAD CO.; STANDARD STEEL WORKS CO. Supports 3 ft. Center to Center, Carried on M. C. B. Drop-Test Machine.		NEW YORK CENTRAL LINE, Rigid Supports 5 ft. Center to Center. CARNEGIE STEEL CO., Rigid Supports at Ends of Forgings.
	Height of Drop, ft. and in.		
	1640-lb. Tup.	2240-lb. Tup.	Energy of Blow, ft.-lb.
4½	0 ft. 11 in.	....	700
5	1 " 3 "	....	900
5½	1 " 8 "	1 ft. 2 in.	1 200
6	2 " 2 "	1 " 7 "	1 700
6½	2 " 9 "	2 " 0 "	2 500
7	3 " 5 "	2 " 6 "	3 500
7½	4 " 3 "	3 " 1 "	4 700
8	5 " 1 "	3 " 8 "	6 000
8½	6 " 2 "	4 " 6 "	7 500
9	7 " 3 "	5 " 3 "	9 000
9½	8 " 7 "	6 " 8 "	10 000
10	10 " 0 "	7 " 4 "	11 000
10½	11 " 7 "	8 " 6 "	12 000
11	13 " 5 "	9 " 10 "	13 000
11½	15 " 3 "	11 " 1 "	14 000
12	17 " 4 "	12 " 8 "	15 000

The Pennsylvania System and the Standard Steel Works Co. require that all axles, shafts and similar forgings shall undergo an impact proof test on an A. R. A. drop-test machine, with supports spaced 3 ft. center to center, two blows being struck with a tup weighing 1640 or 2240 lb. The forging is to have one of the points of support as near as practicable to one end for the first blow and as near as practicable to the other end for the second blow, the forging being turned 90 deg. on its longitudinal axis after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas:

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[1] For more detailed information concerning these methods of proof testing, see Report of Committee A-1 on Standard Specifications for Steel, Appendix IV, "Report on Proof Tests of Finished Forgings," *Proceedings*, Am. Soc. Test. Mats., Vol. XIV, Part I, p. 120 (1914). Also, Report of Committee A-1 for 1917; *ibid*, Vol. XVII, Part I, pp. 115–117 (1917).

$$\text{For the 1640-lb. tup: } H = 0.01\,D^3$$
$$\text{For the 2240-lb. tup: } H = 0.0073\,D^3$$

in which H is the height of drop in feet and D is the diameter of the forging at the center in inches.

The New York Central Lines and the Carnegie Steel Co. require that forgings shall be submitted to an impact proof test by having them carried on rigid supports and struck one blow at the center by a tup delivering the number of foot-pounds of energy shown in the accompanying table. The New York Central Lines space the supports 5 ft. center to center, while the Carnegie Steel Co. places the supports as near as practicable to the ends of the forgings.

STANDARD SPECIFICATIONS
FOR
QUENCHED-AND-TEMPERED ALLOY-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS.

Serial Designation: A 63 – 21.

These specifications are issued under the fixed designation A 63; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1918, 1921.

Material Covered. 1. (*a*) These specifications cover the various classes of alloy-steel forgings now commonly used in locomotive and car construction.

(*b*) The purposes for which these classes are frequently used are as follows:

Class K, for forgings for main and side rods, straps, piston rods, and all other forgings which are to be machined with milling cutters or complicated forming tools;

Class L, for forgings for driving and trailing-truck axles, crank pins, and other parts not requiring the use of milling cutters or complicated forming tools.

I. MANUFACTURE.

Process. 2. The steel shall be made by either or both the following processes: open-hearth or electric furnace.

Discard. 3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests. 4. For test purposes, a prolongation shall be left on each forging, unless otherwise specified by the purchaser.

Boring. 5. (*a*) Unless otherwise specified by the purchaser, all forgings over 7 in. in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring shall be done before quenching.

(*b*) If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperatire below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly."

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

7. (*a*) The steel shall conform to the following requirements as to chemical composition:

	ACID.	BASIC.
Phosphorus...........	not over 0.05	not over 0.04 per cent
Sulfur................	" " 0.05	" " 0.05 "

(*b*) The composition of alloy steel, other than phosphorus and sulfur, shall be agreed upon by the manufacturer and the purchaser.

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese and the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. (*a*) An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

(*b*) In addition to the complete analysis specified in Paragraph (*a*), a phosphorus determination may be made by the purchaser from each broken tension test specimen. The phosphorus content thus determined shall conform to the requirement specified in Section 7.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 10. (*a*) The forgings shall conform to the requirements as to tensile properties specified in Table I.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*d*) Tests of forgings shall be made only after final treatment.

Bend Tests. 11. If specified by the purchaser, bend tests shall be made as follows:

(*a*) For the first, second and third classes by size, the test specimen shall withstand being bent cold through 180 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

(*b*) For the fourth and fifth classes by size, the test specimen shall withstand being bent cold through 180 deg. around a pin $1\frac{1}{2}$ in. in diameter, without cracking on the outside of the bent portion.

Proof Tests. 12. Unless otherwise specified by the purchaser, all forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.[1]

Test Specimens. 13. (*a*) Tension and bend test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

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[1] For information relative to proof tests of finished forgings, see Appendix, pp. 168–169.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

TABLE I.—TENSILE PROPERTIES.

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

CLASS	SIZE.	Tensile Strength, lb. per. sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent.	Reduction of Area, min., per cent.
K ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall..	95 000 - 115 000	70 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall......................	90 000 - 110 000	65 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max wall......................	90 000 - 110 000	65 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall......................	90 000 - 110 000	65 000	20	50
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall.	85 000 - 105 000	60 000	20	50
L ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall...	105 000 - 125 000	80 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max wall......................	100 000 - 120 000	75 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall......................	100 000 - 120 000	75 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall......................	100 000 - 120 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	95 000 - 115 000	70 000	18	45

Number of Tests.

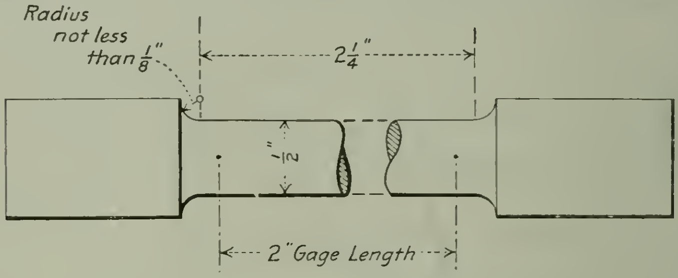
14. (*a*) One tension and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension and, if specified, one bend test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension and, if specified, one bend test from a forging of each class by size shall be made as specified in Sections 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any tension test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 15. (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 14.



Note:—The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*b*) If the fracture of any tension test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be retempered or requenched and tempered. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

IV. WORKMANSHIP AND FINISH.

Workmanship. 16. The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance of $\frac{1}{8}$ in. on the surface for finishing. In centering, 60-deg. centers with clearance drilled for points shall be used.

Finish. 17. The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 18. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION.

Inspection. 19. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 19 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 21. Samples tested in accordance with Section 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

APPENDIX.

As a guide in deciding on a proof test for quenched-and-tempered forgings, the following particulars regarding three established methods of testing are given.[1] These methods of proof testing are giving satisfactory results in practice.

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS.

Diameter, in.	PENNSYLVANIA RAILROAD CO.; STANDARD STEEL WORKS CO. Supports 3 ft. Center to Center, Carried on M. C. B. Drop-Test Machine.		NEW YORK CENTRAL LINES, Rigid Supports 5 ft. Center to Center. CARNEGIE STEEL CO., Rigid Supports at Ends of Forgings.
	Height of Drop, ft. and in.		
	1640-lb. Tup.	2240-lb. Tup.	Energy of Blow, ft.-lb.
4½	0 ft. 11 in.	....	700
5	1 " 3 "	....	900
5½	1 " 8 "	1 ft. 2 in.	1 200
6	2 " 2 "	1 " 7 "	1 700
6½	2 " 9 "	2 " 0 "	2 500
7	3 " 5 "	2 " 6 "	3 500
7½	4 " 3 "	3 " 1 "	4 700
8	5 " 1 "	3 " 8 "	6 000
8½	6 " 2 "	4 " 6 "	7 500
9	7 " 3 "	5 " 3 "	9 000
9½	8 " 7 "	6 " 3 "	10 000
10	10 " 0 "	7 " 4 "	11 000
10½	11 " 7 "	8 " 6 "	12 000
11	13 " 5 "	9 " 10 "	13 000
11½	15 " 3 "	11 " 1 "	14 000
12	17 " 4 "	12 " 8 "	15 000

The Pennsylvania System and the Standard Steel Works Co. require that all axles, shafts and similar forgings shall undergo an impact proof test on an A. R. A. drop-test machine, with supports spaced 3 ft. center to center, two blows being struck with a tup weighing 1640 or 2240 lb. The forging is to have one of the points of support as near as practicable to one end for the first blow and as near as practicable to the other end for the second blow, the forging being turned 90 deg. on its longitudinal axis after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas:

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[1] For more detailed information concerning these methods of proof testing, see Report of Committee A-1 on Standard Specifications for Steel, Appendix IV, "Report on Proof Tests of Finished Forgings," *Proceedings*, Am. Soc. Test. Mats., Vol. XIV, Part I, p. 120 (1914). Also, Report of Committee A-1 for 1917; *ibid*, Vol. XVII, Part I, pp. 115-117 (1917)

For the 1640-lb. tup: $H = 0.01\ D^3$
For the 2240-lb. tup: $H = 0.0073\ D^3$

in which H is the height of drop in feet and D is the diameter of the forging at the center in inches.

The New York Central Lines and the Carnegie Steel Co. require that forgings shall be submitted to an impact proof test by having them carried on rigid supports and struck one blow at the center by a tup delivering the number of foot-pounds of energy shown in the accompanying table. The New York Central Lines space the supports 5 ft. center to center, while the Carnegie Steel Co. places the supports as near as practicable to the ends of the forgings.

STANDARD SPECIFICATIONS

FOR

CARBON-STEEL FORGINGS FOR LOCOMOTIVES.

Serial Designation: A 20 – 21.

These specifications are issued under the fixed designation A 20; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916, 1921.

Material Covered. 1. These specifications cover untreated and annealed carbon-steel driving axles, engine and trailing-truck axles, main and side rods, straps, crank pins and piston rods.

Basis of Purchase. 2. The manufacturer may, at his option, furnish annealed forgings when untreated forgings are specified by the purchaser, provided they conform to the requirements specified for untreated forgings.

I. MANUFACTURE.

Process. 3. The steel shall be made by either or both the following processes: open-hearth or electric furnace.

Discard. 4. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests. 5. The manufacturer and the purchaser shall agree upon forgings on which a prolongation for test purposes shall be provided.

Heat Treatment. 6. The procedure to be followed in annealing shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 7. The steel shall conform to the following requirements as to chemical composition:

Manganese		0.40 – 0.70	per cent
Phosphorus	not over	0.05	"
Sulfur	" "	0.05	"

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon and the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface; or turnings may be taken from a test specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

10. (*a*) The forgings shall conform to the minimum requirements as to tensile properties specified in Table I.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

(*d*) Tests of forgings shall be made only after final treatment.

Tension Test Specimens.

11. (*a*) Tension test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of the forging, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

12. Unless otherwise specified by the purchaser, tests shall be made as follows:

(*a*) For untreated forgings, one tension test shall be made from each melt.

(*b*) For annealed forgings, one tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension test shall be made from each melt.

(*c*) If more than one class of forgings by size is represented in any lot, one tension test from a forging of each class by size shall be made as specified in Sections 10 and 11.

(*d*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

TABLE I.—TENSILE PROPERTIES.

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 12-IN. WHEN UNTREATED AND NOT OVER 20 IN. WHEN ANNEALED.

UNTREATED.

SIZE. Outside Diameter or Over-all Thickness.	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent.		Reduction of Area, per cent.	
			Inverse Ratio.	Not under	Inverse Ratio.	Not under
Not over 8 in.................	75 000	0.5 tens. str.	$\frac{1\,600\,000}{\text{Tens. str.}}$	18	$\frac{2\,200\,000}{\text{Tens. str.}}$	24
Over 8 to 12 in., inclusive.......	75 000	0.5 tens. str.	$\frac{1\,500\,000}{\text{Tens. str.}}$	17	$\frac{2\,000\,000}{\text{Tens. str.}}$	22
ANNEALED.						
Not over 8 in.................	80 000	0.5 tens. str.	$\frac{1\,800\,000}{\text{Tens. str.}}$	20	$\frac{2\,800\,000}{\text{Tens. str.}}$	32
Over 8 to 12 in., inclusive.......	80 000	0.5 tens. str.	$\frac{1\,725\,000}{\text{Tens. str.}}$	19	$\frac{2\,640\,000}{\text{Tens. str.}}$	30
Over 12 to 20 in., inclusive......	80 000	0.5 tens. str.	$\frac{1\,650\,000}{\text{Tens. str.}}$	18	$\frac{2\,400\,000}{\text{Tens. str.}}$	28

(*e*) If the percentage of elongation of any test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 13. (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 12.

(*b*) When annealed forgings are specified, if the fracture of any test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be re-annealed. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

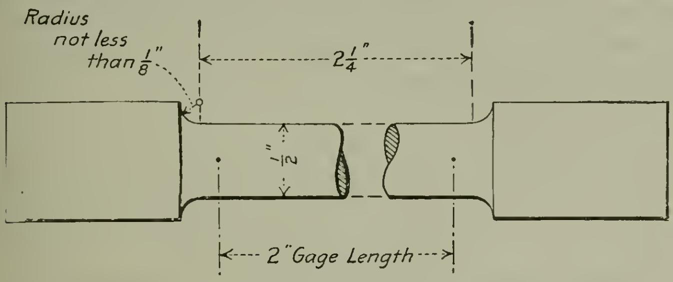
IV. WORKMANSHIP AND FINISH.

Workmanship.

14. The forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish

15. The forgings shall be free from injurious defects and shall have a workmanlike finish



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

V. MARKING.

Marking.

16. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION.

Inspection.

17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 17 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 19. Samples tested in accordance with Section 17 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL CAR AND TENDER AXLES.

Serial Designation: A 21 – 18.

These specifications are issued under the fixed designation A 21; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1901; Revised, 1905, 1913, 1914, 1918.

Material Covered.

1. These specifications cover axles up to and including those 6½ in. in diameter at the center. Axles over 6½ in. in diameter at the center shall not be subject to the drop test, but may be purchased under the Standard Specifications for Carbon-Steel and Alloy-Steel Forgings (Serial Designation: A 18) of the American Society for Testing Materials.

I. MANUFACTURE.

Process.

2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.35 – 0.55	per cent
Manganese	not over 0.70	"
Phosphorus	" " 0.05	"
Sulfur	" " 0.06	"

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from an axle representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analysis may be taken from the axle or from a full-size prolongation of the same, at any point midway between the center and surface.

III. PHYSICAL PROPERTIES AND TESTS.

Drop Tests. 6. (*a*) The test axle shall be so placed on supports 3 ft. apart that the tup will strike it midway between the ends. It shall stand without fracture five blows from a tup of 2240 lb. falling from a height H, such that H in feet equals the square of the diameter of the axle at the center in inches, $H = d^2$. The axle shall be turned through 180 deg. after the first and third blows.

(*b*) The permanent set produced by the first blow shall not exceed that given by the following formulas, in which L = length of axles in inches and d = diameter of axle at center in inches:

For axles over 65 in. in length:

$$\left(\frac{L}{1.9d} - \frac{d}{2}\right) + \tfrac{1}{2} \text{ in} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

For axles 65 in. or under in length:

$$\left(\frac{L}{1.9d} - \frac{d}{2}\right) + 1 \text{ in} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(*c*) The American Railway Association, Mechanical Section, has adopted four standard sizes of axles, the requirements for which, based on the above formula (1), are given in the following table:

Size of Journal, in.	Diameter of Axle at Center, in.	Length of Axle, in.	Height of Drop, ft.	Number of Blows.	Maximum Permanent Set, in.
$4\frac{1}{4}$ by 8	$4\frac{3}{4}$	$84\frac{1}{4}$	$22\frac{1}{2}$	5	$7\frac{1}{2}$
5 by 9	$5\frac{3}{8}$	$86\frac{1}{2}$	29	5	$6\frac{1}{4}$
$5\frac{1}{2}$ by 10	$5\frac{7}{8}$	$88\frac{1}{2}$	$34\frac{1}{2}$	5	$5\frac{1}{2}$
6 by 11	$6\frac{7}{16}$	$90\frac{3}{4}$	$41\frac{1}{2}$	5	$4\frac{3}{4}$

(*d*) The maximum permanent set is the difference between the distance from a straight edge to the middle point of the axle, measured before the first blow, and the distance measured in the same manner after the blow. The straight edge shall rest only on the collars or the ends of the axle.

(*e*) The temperature of the test axle shall be between 40 and 120° F.

Drop-Test Machine. 7. The anvil of the drop-test machine shall be supported on 12 springs, shall be free to move in a vertical direction, and shall weigh 17,500 lb. The radii of the striking face of the tup and of the supports shall be 5 in.

Number of Tests. 8. One drop test shall be made from each melt. Not less than 30 axles shall be offered from any one melt, unless otherwise agreed upon by the manufacturer and the purchaser.

IV. WORKMANSHIP AND FINISH.

Workmanship. 9. The axles shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish. 10. The axles shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 11. Identification marks shall be legibly stamped on each axle. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION.

Inspection. 12. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the axles ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the axles are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the chemical tests to govern the acceptance or rejection of the axles in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 13. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 12(*b*) shall be reported within five working days from the receipt of samples.

(*b*) Axles which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing 14. Samples tested in accordance with Section 12 (*b*), which represent rejected axles, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS

FOR

COLD-ROLLED STEEL AXLES.

Serial Designation: A 22 – 21.

These specifications are issued under the fixed designation A 22; the final number indicates the year of original adoption as standard, or in the ease of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914, 1916, 1921.

I. MANUFACTURE.

Process. 1. (*a*) The steel shall be made by either or both the following processes: open-hearth or electric furnace.

(*b*) The axles shall be cold-rolled to finished size from hot-rolled bars.

Discard. 2. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Carbon	not over 0.40 per cent
Manganese	0.40 – 0.80 "
Phosphorus	not over 0.05 "
Sulfur	" " 0.05 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from an axle representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analysis may be taken from the axle or from a full-size prolongation of the same, at any point midway between the center and surface; or turnings may be taken from a test specimen.

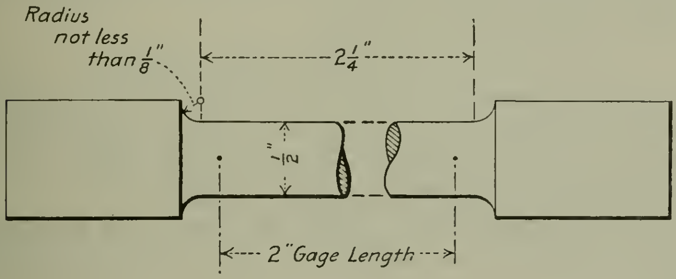
III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The axles shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	70 000
Elastic limit, " "	60 000
Elongation in 2 in., per cent	18
Reduction of area, "	35

(*b*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

Bend Tests.

7. The test specimen shall bend cold through 180 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

Test Specimens

8. (*a*) Tension and bend test specimens shall be taken from the full-size prolongation of the axle. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the axle.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*c*) Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests. 9. (*a*) One tension and one bend test shall be made from each lot of 50 axles or less from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6(*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. WORKMANSHIP AND FINISH.

Workmanship. 10. The axles shall conform to the sizes and shapes specified by the purchaser, and shall not vary more than 0.002 in. from the diameter specified. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish. 11. The axles, either finished or plain, shall be straight and free from injurious defects, and shall have a workmanlike finish.

V. MARKING.

Marking. 12. Identification marks shall be legibly stamped on each axle, and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION.

Inspection. 13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the axles ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the axles are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the axles in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Axles which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 15. Samples tested in accordance with Section 13 (*b*), which represent rejected axles, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
WROUGHT SOLID CARBON-STEEL WHEELS FOR STEAM RAILWAY SERVICE.

Serial Designation: A 57 - 16.

These specifications are issued under the fixed designation A 57; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1916.

I. MANUFACTURE.

Process 1. The steel shall be made by the open-hearth process.

Discard. 2. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

	ACID.	BASIC.	
Carbon	0.60 – 0.80	0.65 – 0.85	per cent
Manganese	0.55 – 0.80	0.55 – 0.80	"
Phosphorus	not over 0.05	not over 0.05	"
Sulfur	" " 0.05	" " 0.05	"
Silicon	0.15 – 0.35	0.10 – 0.30	"

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a wheel representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the usefulness of the wheel. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together.

III. MATING.

Mating.

6. The wheels shall be mated as to tape sizes and shipped in pairs.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.[1]

Permissible Variations.

7. The wheels shall conform to the dimensions specified within the following permissible variations:

FLANGE.

(*a*) *Height of Flange.*—The height of flange shall not be less, but may be $\frac{1}{8}$ in. more than that specified.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary more than $\frac{1}{16}$ in. from that specified.

(*c*) *Radius of Throat.*—The radius of throat shall not vary more than $\frac{1}{16}$ in. from that specified.

RIM.

(*d*) *Thickness of Rim.*—The rim may vary in thickness, but the variation less than that specified shall not exceed $\frac{3}{16}$ in. The thickness of rim shall be measured from the inner edge of the rim to a base line drawn from the intersection of the throat radius and the tread, parallel to the axis of the wheel.

(*e*) *Width of Rim.*—The width of rim shall not vary more than $\frac{1}{8}$ in. from that specified.

(*f*) *Plane.*—The wheels shall be gaged with a ring gage placed concentric with and perpendicular to the axis of the wheel. For all points on the back face of the rim equidistant from the center, the variation from the plane of the gage when so placed shall not exceed $\frac{1}{16}$ in.

(*g*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed $\frac{1}{16}$ in.

(*h*) *Block Marks on Tread.*—Block marks shall not exceed $\frac{1}{64}$ in. in height.

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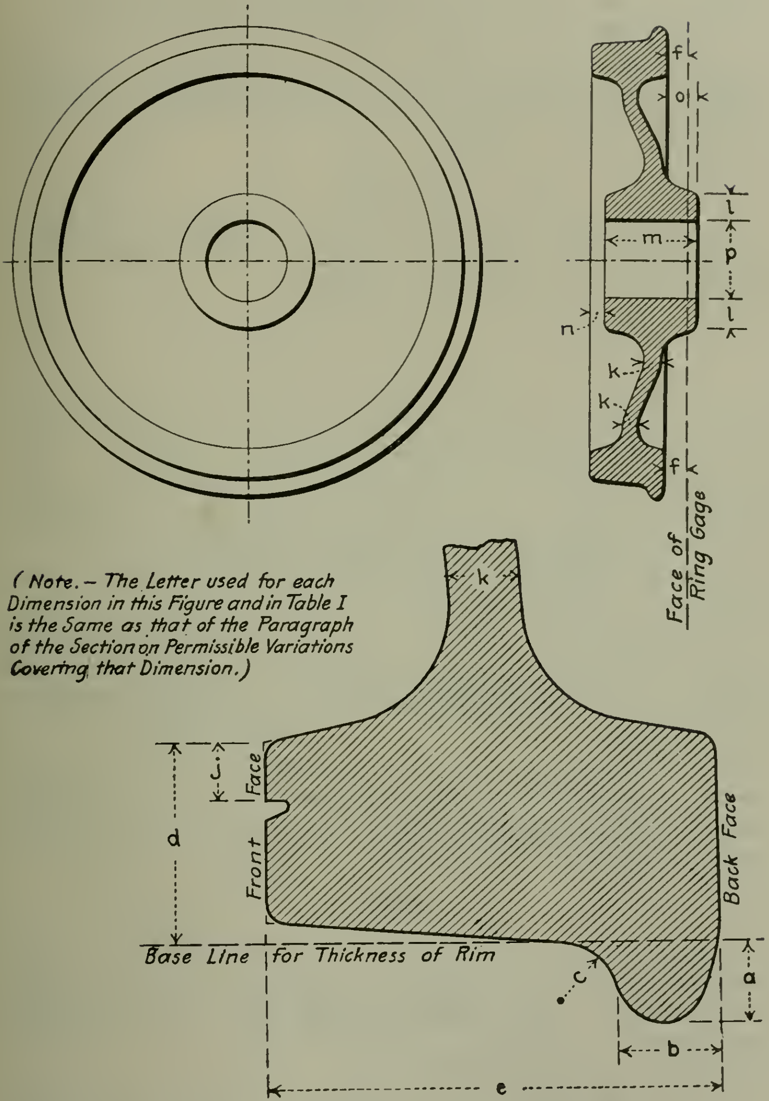
[1] To facilitate the use of the specifications, the various dimensions are illustrated in Fig. 1, and the permissible variations in those dimensions are also given in tabular form in Table I.

TABLE I.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF WROUGHT-STEEL WHEELS FOR STEAM RAILWAY SERVICE.

Dimensions.	Permissible Variations in Dimensions.	
	Over	Under
FLANGE.		
(a) Height	$\frac{1}{8}$ in.	0
(b) Thickness	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
(c) Radius of Throat	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
RIM.		
(d) Thickness, from Inner Edge to Intersection of Throat and Tread	......	$\frac{3}{16}$ in.
(e) Width	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
(f) Maximum Departure of any Circle on Back Face from Plane	$\frac{1}{16}$ in.	
(g) Maximum Departure of Tread from Rotundity	$\frac{1}{16}$ in.	
(h) Maximum Height of Block Marks on Tread	$\frac{1}{64}$ in.	
(i) Tape Sizes	9	5
(j) Limit-of-Wear Groove:		
1. Maximum Departure from Specified Position	$\frac{1}{8}$ in.	
2. Minimum Distance from Inner Edge of Rim	$\frac{3}{4}$ in.	
PLATE.		
(k Thickness, Variation foı each $\frac{1}{2}$ in. of thickness	......	$\frac{1}{32}$ in.
HUB.		
(l) 1. Diameter	......	Limited by wall thickness
2. Minimum Thickness of Wall, for Bore 7 in. or under	$1\frac{1}{8}$ in.	
3. Minimum Thickness of Wall, for Bore over 7 in	$1\frac{3}{8}$ in.	
4. Maximum Variation in Thickness of Wall in any One Wheel	$\frac{3}{8}$ in.	
(m) Length	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
(n) Depression below Front Face of Rim	$\frac{1}{8}$ in.	0
(o) Projection beyond Back Face of Rim	$\frac{1}{8}$ in.	0
BORE. (If not specified, Rough Bore shall be $\frac{1}{4}$ in. less than Finished Bore.)		
(p) Diameter of Rough Bore	$\frac{1}{16}$ in.	$\frac{1}{8}$ in.
(q) Maximum Depth of Black Spots in Rough Bore within 2 in. of End of Bore	$\frac{1}{16}$ in.	
(r) Maximum Eccentricity of Rough Bore in Relation to Tread	$\frac{3}{64}$ in.	

NOTE.—The letter used for each dimension in this table and in Fig. 1 is the same as that of the paragraph of Section 7 covering that dimension.



(Note.—The Letter used for each Dimension in this Figure and in Table I is the Same as that of the Paragraph of the Section on Permissible Variations Covering that Dimension.)

FIG. 1.—Diagram showing Points at which the Dimensions covered by the Specifications are Measured. For the Permissible Variations in these Dimensions see Table I or Section 7.

(*i*) *Tape Sizes.*—The wheels shall not vary more than 9 tapes over nor more than 5 tapes under the size specified.

(*j*) *Limit-of-Wear Groove.*—When a limit-of-wear groove is specified, its location shall not vary more than $\frac{1}{8}$ in. from that specified, and its distance from the inner edge of the rim shall not at any point be less than $\frac{3}{4}$ in.

PLATE.

(*k*) *Thickness of Plate.*—The plate may vary in thickness, but the variation less than that specified shall not exceed $\frac{1}{32}$ in. for each $\frac{1}{8}$ in. in the thickness of the plate.

HUB.

(*l*) *Diameter of Hub.*—The diameter of hub may vary, but the thickness of wall of the finished bored hub shall not be less than $1\frac{1}{8}$ in. at any point for bores 7 in. or under in diameter, nor less than $1\frac{3}{8}$ in. for bores over 7 in. in diameter, unless otherwise specified. The thickness of wall of the hub shall not vary more than $\frac{3}{8}$ in. at any two points on the same wheel.

(*m*) *Length of Hub.*—The length of hub shall not vary more than $\frac{1}{8}$ in. from that specified.

(*n*) *Depression of Hub*—For car and tender wheels and wheels of similar design, the depression of the hub below the front face of the rim shall not be less, but may be $\frac{1}{8}$ in. more than that specified.

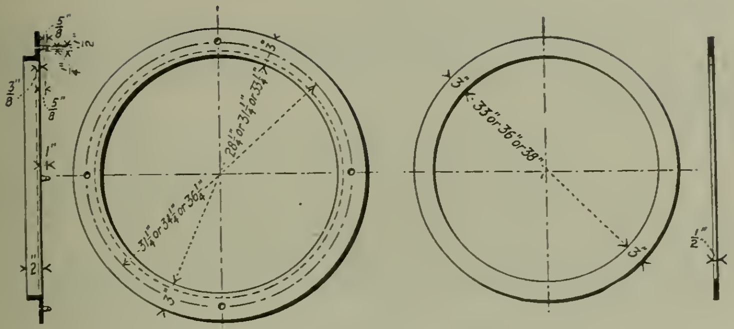
(*o*) *Projection of Hub.*—For locomotive-truck wheels and wheels of similar design, the projection of the hub beyond the back face of the rim shall not be less, but may be $\frac{1}{8}$ in. more than that specified.

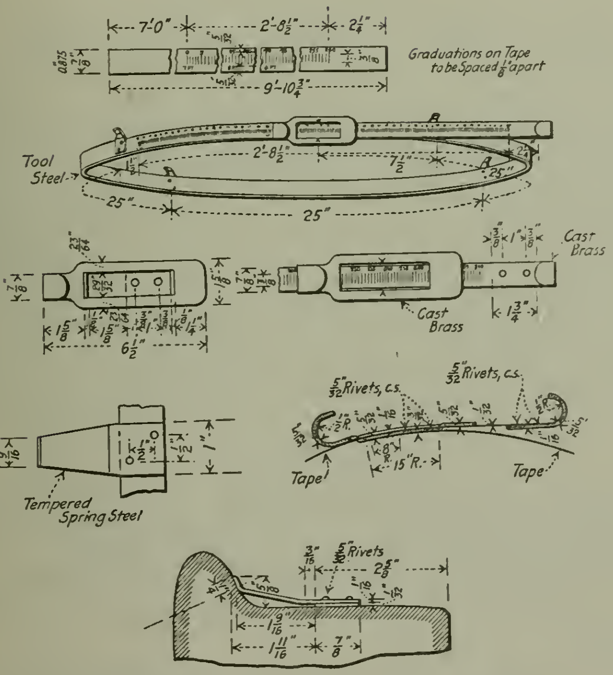
BORE.

(*p*) *Diameter of Rough Bore.*—The diameter of rough bore shall not vary more than $\frac{1}{16}$ in. over nor more than $\frac{1}{8}$ in. under that specified. When finished-bore diameter only is specified, the rough-bore diameter shall be made $\frac{1}{4}$ in. less with the permissible variations specified above.

(*q*) *Black Spots in Bore.*—Black spots in rough bore within 2 in. of either face of the hub shall not exceed $\frac{1}{16}$ in. in depth.

(*r*) *Eccentricity of Bore.*—The eccentricity between the tread at its center line and the rough bore shall not exceed $\frac{3}{64}$ in.





(*c*) Tape for Wheel Circumference Measure.

FIG. 2.—American Railroad Association Standards.

V. FINISH.

Finish. 8. (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust, or any other substance to such an extent as to hide defects.

VI. MARKING.

Marking. 9. (*a*) The name or brand of the manufacturer, date, and serial number shall be legibly stamped on each wheel in such a way that the wheel may be readily identified.

(*b*) The tape size shall be legibly marked on each wheel.

VII. INSPECTION AND REJECTION.

Inspection. 10. (*a*) The gages and tapes used shall be based on American Railroad Association standards, as illustrated in Fig. 2.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of wheels in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 10 (*c*) shall be reported within five working days from the receipt of samples.

(*b*) Wheels which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 12. Samples tested in accordance with Section 10 (*c*), which represent rejected wheels, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
WROUGHT SOLID CARBON-STEEL WHEELS FOR ELECTRIC RAILWAY SERVICE.

Serial Designation: A 25 – 16.

These specifications are issued under the fixed designation A 25; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1916.

Material Covered. 1. These specifications cover two classes of wheels, as follows:

Class A: Wheels furnished rough-bored with hub faced on both sides, and other surfaces as rolled or forged.

Class B: Wheels furnished rough-bored with hubs faced on both sides, and front face of rim, tread, flange, and back face of rim machined.

Basis of Purchase. 2. The class of wheel to be furnished shall be agreed upon by the manufacturer and the purchaser. Wheels ordered to Class A may be machined if necessary, but the permissible variations from the dimensions specified shall remain those given in Section 9 for Class A.

I. MANUFACTURE.

Process. 3. The steel shall be made by the open-hearth process.

Discard. 4. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 5. The steel shall conform to the following requirements as to chemical composition:

	ACID.	BASIC.	
Carbon................	0.60 – 0.80	0.65 – 0.85	per cent
Manganese............	0.55 – 0.80	0.55 – 0.80	"
Phosphorus...........	not over 0.05	not over 0.05	"
Sulfur................	" " 0.05	" " 0.05	"
Silicon................	0.15 – 0.35	0.10 – 0.30	"

Ladle Analyses

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 5. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

Check Analyses.

7. An analysis may be made by the purchaser from a wheel representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 5. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the usefulness of the wheel. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together.

III. MATING.

Mating.

8. The wheels shall be mated as to tape sizes and shipped in pairs.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.[1]

9. The wheels shall conform to the dimensions specified within the following permissible variations:

FLANGE.

Permissible Variations.

(*a*) *Height of Flange.*—The height of flange shall not vary from that specified more than $\frac{1}{16}$ in. for Class A or $\frac{1}{32}$ in. for Class B wheels.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary from that specified more than $\frac{1}{16}$ in. for Class A or $\frac{1}{32}$ in. for Class B wheels.

(*c*) *Radius of Throat.*—The radius of throat shall not vary from that specified more than $\frac{1}{16}$ in. for Class A or $\frac{1}{32}$ in. for Class B wheels.

RIM.

(*d*) *Thickness of Rim.*—The thickness of rim shall not vary more than $\frac{1}{4}$ in. over nor more than $\frac{1}{8}$ in. under that specified.

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[1] To facilitate the use of the specifications, the various dimensions are illustrated in Fig. 1, and the permissible variations in those dimensions are also given in tabular form in Table I

The thickness of rim shall be measured from the inner edge of the rim to a base line drawn from the intersection of the throat radius and the tread, parallel to the axis of the wheel.

(*e*) *Width of Rim.*—The width of rim shall not vary from that specified more than $\frac{1}{8}$ in. for Class A or $\frac{1}{16}$ in. for Class B wheels.

(*f*) *Plane.*—The wheels shall be gaged with a ring gage placed concentric with and perpendicular to the axis of the wheel. For all points on the back of the rim equidistant from the center, the variation from the plane of the gage when so placed shall not exceed $\frac{1}{16}$ in. for Class A or $\frac{1}{32}$ in. for Class B wheels.

(*g*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed $\frac{1}{16}$ in. for Class A wheels or $\frac{1}{64}$ in. for Class B wheels.

(*h*) *Block Marks on Tread.*—Block marks shall not exceed $\frac{1}{64}$ in. in height.

(*i*) *Tape Sizes.*—Wheels with treads under 3 in. in width shall not vary more than 6 tapes over nor more than 4 tapes under the size specified. Wheels with treads 3 in. or over in width shall not vary more than 9 tapes over nor more than 5 tapes under the size specified.

(*j*) *Limit-of-Wear Groove.*—When a limit-of-wear groove is specified, its location shall not vary more than $\frac{1}{16}$ in. from that specified.

PLATE.

(*k*) *Thickness of Plate.*—The plate may vary in thickness, but the variation less than that specified shall not exceed $\frac{1}{32}$ in. for each $\frac{1}{8}$ in. in the thickness of the plate.

HUB.

(*l*) *Diameter of Hub.*—The diameter of hub shall not be less, but may be $\frac{3}{4}$ in. more than that specified. The thickness of wall of the finished bored hub shall not be less than 1 in. at any point for bores 6 in. or under in diameter, nor less than $1\frac{1}{4}$ in. for bores over 6 in. in diameter, unless otherwise specified. The thickness of wall of the hub shall not vary more than $\frac{3}{8}$ in. at any two points on the same wheel.

(*m*) *Length of Hub.*—The length of hub shall not vary more than $\frac{1}{8}$ in. from that specified.

(*o*) *Projection of Hub.*—The projection of the hub beyond the back face of the rim shall not vary more than $\frac{1}{16}$ in. from that specified.

BORE.

(*p*) *Diameter of Rough Bore.*—The diameter of rough bore shall not vary more than $\frac{1}{16}$ in. over nor more than $\frac{1}{8}$ in. under that specified. When finished-bore diameter only is specified, the rough-bore diameter shall be made $\frac{1}{4}$ in. less with the permissible variations specified above.

(*q*) *Black Spots in Bore.*—Black spots in rough bore within 2 in. of either face of the hub shall not exceed $\frac{1}{16}$ in. in depth.

(*r*) *Eccentricity of Bore.*—The eccentricity between the tread at its center line and the rough bore shall not exceed $\frac{3}{64}$ in.

V. FINISH.

Finish.

10. (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust or any other substance to such an extent as to hide defects.

VI. MARKING.

Marking.

11. (*a*) The name or brand of the manufacturer, date, and serial number, shall be legibly stamped on each wheel in such a way that the wheel may be readily identified.

(*b*) The tape size shall be legibly marked on each wheel.

VII. INSPECTION AND REJECTION.

Inspection.

12. (*a*) The manufacturer shall provide suitable gages and tapes, which shall conform to the contour and dimensions specified.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

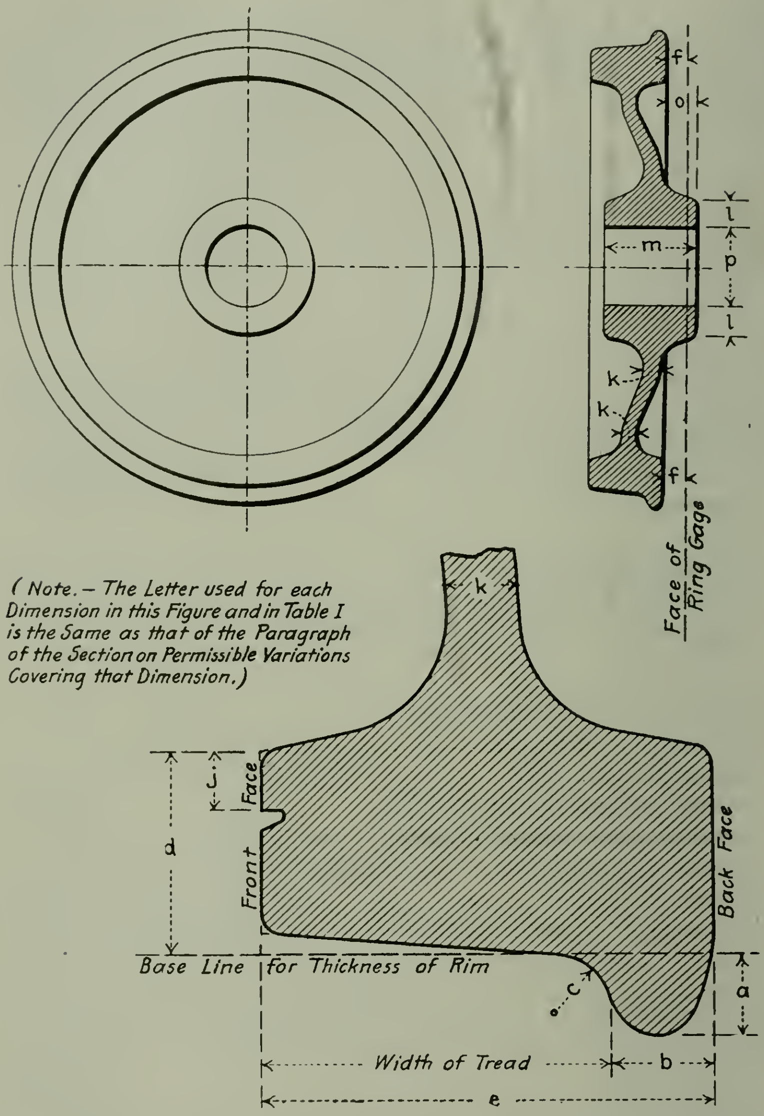
(*c*) The purchaser may make the tests to govern the acceptance or rejection of wheels in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE I.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF WROUGHT-STEEL WHEELS FOR ELECTRIC RAILWAY SERVICE.

Dimensions.	Permissible Variations in Dimensions.			
	Class A.		Class B.	
	Over	Under	Over	Under
FLANGE.				
(a) Height	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.
(b) Thickness	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.
(c) Radius of Throat	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.
RIM.				
(d) Thickness, from Inner Edge to Intersection of Throat and Tread	$\frac{1}{4}$ in.	$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	$\frac{1}{8}$ in.
(e) Width	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
(f) Maximum Departure of any Circle on Back Face from Plane	$\frac{1}{16}$ in.		$\frac{1}{32}$ in	
(g) Maximum Departure of Tread from Rotundity	$\frac{1}{16}$ in.		$\frac{1}{64}$ in.	
(h) Maximum Height of Block Marks on Tread	$\frac{1}{64}$ in.		$\frac{1}{64}$ in.	
(i) Tape Sizes:				
1. For Treads under 3 in. in Width	6	4	6	4
2. For Treads 3 in. or over in Width	9	5	9	5
(j) Limit-of-Wear Groove: Maximum Departure from Specified Position	$\frac{1}{16}$ in.		$\frac{1}{16}$ in.	
PLATE.				
(k) Thickness, Variation for each $\frac{1}{8}$ in. of Thickness	....	$\frac{1}{32}$ in.	....	$\frac{1}{32}$ in.
HUB.				
(l) 1. Diameter	$\frac{3}{4}$ in.	0	$\frac{3}{4}$ in.	0
2. Minimum Thickness of Wall, for Bore 6 in. or under	1 in.		1 in.	
3. Minimum Thickness of Wall, for Bore over 6 in	$1\frac{1}{4}$ in.		$1\frac{1}{4}$ in.	
4. Maximum Variation in Thickness of Wall in any One Wheel	$\frac{3}{8}$ in.		$\frac{3}{8}$ in.	
(m) Length	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
(o) Projection beyond Back Face of Rim	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
BORE. (If not specified, Rough Bore shall be $\frac{1}{4}$ in. less than Finished Bore.)				
(p) Diameter of Rough Bore	$\frac{1}{16}$ in.	$\frac{1}{8}$ in.	$\frac{1}{16}$ in.	$\frac{1}{8}$ in.
(q) Maximum Depth of Black Spots in Rough Bore within 2 in. of End of Bore	$\frac{1}{16}$ in.		$\frac{1}{16}$ in.	
(r) Maximum Eccentricity of Rough Bore in Relation to Tread	$\frac{3}{64}$ in.		$\frac{3}{64}$ in.	

NOTE.—The letter used for each dimension in this table and in Fig. 1 is the same as that of the paragraph of Section 9 covering that dimension.



(Note.— The Letter used for each Dimension in this Figure and in Table I is the Same as that of the Paragraph of the Section on Permissible Variations Covering that Dimension.)

FIG. 1.—Diagram showing Points at which the Dimensions covered by the Specifications are Measured. For the Permissible Variations in these Dimensions see Table I or Section 9.

13. (*a*) Unless otherwise specified any rejection based on tests made in accordance with Section 12 (*c*) shall be reported within ten working days from receipt of samples. **Rejection.**

(*b*) Wheels which show injurious defects while being finished by purchaser will be rejected, and the manufacturer shall be notified.

14. Samples tested in accordance with Section 12 (*c*), which represent rejected wheels, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS
FOR
STEEL TIRES.

Serial Designation: A 26 – 16.

These specifications are issued under the fixed designation A 26; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916.

Material Covered.

1. (*a*) These specifications cover three classes of tires.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for driving tires for passenger locomotives;

Class B, for driving tires for freight locomotives and tires for locomotive-truck, tender-truck, trailer and car wheels, and miscellaneous service;

Class C, for driving tires for switching locomotives.

I. MANUFACTURE.

Process.

2. The steel shall be made by the open-hearth process.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

4. The steel shall conform to the following requirements as to chemical composition:

Carbon	Class A	0.50 – 0.70	per cent
	Class B	0.60 – 0.80	"
	Class C	0.70 – 0.85	"
Manganese		not over 0.75	"
Phosphorus		" " 0.05	"
Sulfur		" " 0.05	"
Silicon		0.15 – 0.35	"

Ladle Analyses.

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser

or his representative, and shall conform to the requirements specified in Section 4.

Check Analyses.

6. An analysis to represent each melt may be made by the purchaser from turnings taken from a tire or from a tension test specimen, if the tension test is specified. The chemical composition thus determined shall conform to the requirements specified in Section 4.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

7. If tension tests from representative bars in accordance with Section 8 are specified by the purchaser, the tensile properties shown shall conform to the following minimum requirements:

	CLASS A.	CLASS B.	CLASS C.
Tensile strength, lb. per sq. in.	105 000	115 000	125 000
Elongation in 2 in., per cent	12	10	8
Reduction of area, "	16	14	12

Tension Test Specimens.

8. (*a*) The tension test specimen representing each melt shall be taken from a test ingot taken during the pouring of the melt, and shall have received approximately the same amount of work as the tires which it represents.

(*b*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

9. (*a*) If specified by the purchaser, one tension test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any test specimen is less than that specified in Section 7 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

10. If the results of the tension test for any melt do not conform to the requirements of Section 7, a retest may be made on a specimen cut from a tire of the same melt furnished at the expense of the manufacturer. This retest shall give results conforming to the requirements of Section 7.

IV. MATING.

Mating.

11. The tires shall be grouped as to outside diameters and shipped in sets.

V. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations.

12. Tires may be furnished with all surfaces as rolled, and shall conform to the dimensions specified within the following permissible variations:

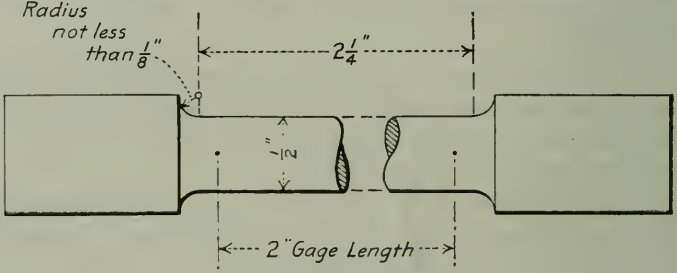
(*a*) *Height of Flange.*—The height of flange shall not vary more than $\frac{3}{32}$ in. from that specified.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary more than $\frac{1}{16}$ in. from that specified.

(*c*) *Radius of Throat.*—The radius of throat shall not vary more than $\frac{1}{8}$ in. over nor more than $\frac{1}{16}$ in. under that specified.

(*d*) *Width of Tire.*—The width of tire shall not vary more than $\frac{1}{8}$ in. over nor more than $\frac{1}{16}$ in. under that specified.

(*e*) *Inside Diameter.*—The rough inside diameter shall not be more, but may be $\frac{1}{4}$ in. less than that specified. When finished inside diameter only is specified, the rough diameter shall be from $\frac{3}{16}$ to $\frac{7}{16}$ in. less than this diameter.



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*f*) *Outside Diameter.*—Unless otherwise specified, the outside diameter when 54 in. or under shall not be less, but may be $\frac{1}{2}$ in. more than that specified; and when over 54 in. shall not vary more than $\frac{1}{8}$ in. under nor more than $\frac{3}{8}$ in. over that specified.

(*g*) *Set Diameters.*—The tires shall be furnished in sets and the variation in outside diameters in each set shall not exceed $\frac{1}{16}$ in. for tires 33 in. or under in outside diameter, nor exceed $\frac{3}{32}$ in. for tires over 33 in. in outside diameter.

(*h*) *Rotundity.*—Tires shall not be out of round more than $\frac{1}{16}$ in. for tires 33 in. or under in outside diameter, nor more than $\frac{3}{32}$ in. for tires over 33 in. in outside diameter.

VI. FINISH.

13. The tires shall be free from injurious defects and shall have a workmanlike finish. **Finish.**

VII. MARKING.

14. The name or brand and serial number of the manufacturer shall be legibly stamped on the tire close to the inside edge, where they will not be removed at the last turning. Set numbers shall be legibly stenciled on each tire. **Marking.**

VIII. INSPECTION AND REJECTION.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tires ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tires are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Tires which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

17. Samples tested in accordance with Section 6, which represent rejected tires, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing**

STANDARD SPECIFICATIONS

FOR

STEEL CASTINGS.

Serial Designation: A 27 – 21.

These specifications are issued under the fixed designation A 27; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1912, 1913, 1914, 1916, 1921.

Material Covered. 1. These specifications cover two classes of castings, namely:

Class A, ordinary castings for which no physical requirements are specified;

Class B, castings for which physical requirements are specified. These are of three grades: hard, medium, and soft.

Patterns. 2. (*a*) Patterns shall be made so that sufficient finish is allowed to provide for all variations in shrinkage.

(*b*) Patterns shall be painted three colors to represent metal, cores, and finished surfaces. It is recommended that core prints shall be painted black and finished surfaces red.

Basis of Purchase. 3. The purchaser shall indicate his intention to substitute the test to destruction specified in Section 11 for the tension and bend tests, and shall designate patterns from which castings for this test shall be made.

I. MANUFACTURE.

Process. 4. The steel shall be made by one or more of the following processes: open-hearth, electric furnace, side blow converter or crucible.

Heat Treatment. 5. (*a*) Class A castings need not be annealed unless so specified.

(*b*) Class B castings shall be properly annealed, the treatment depending upon the design and chemical composition of the castings.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Compositions. 6. The castings shall conform to the following requirements as to chemical composition:

		CLASS A.	CLASS B.
Carbon		not over 0.30 per cent	....
Phosphorus	Acid	" " 0.07 "	not over 0.06 per cent
	Basic	" " 0.06 "	" " 0.05 "
Sulfur		....	" " 0.06 "

Ladle Analyses.

7. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbôn, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

Check Analyses.

8. (*a*) Analyses of Class A castings may be made by the purchaser. The phosphorus content thus determined shall not exceed that specified in Section 6 by more than 20 per cent. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface.

(*b*) Analyses of Class B castings may be made by the purchaser from a broken tension or bend test specimen. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 6 by more than 20 per cent. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface.

III. PHYSICAL PROPERTIES AND TESTS.

(FOR CLASS B CASTINGS ONLY.)

Tension Tests.

9. (*a*) The castings shall conform to the following minimum requirements as to tensile properties:

	HARD.	MEDIUM.	SOFT.
Tensile strength, lb. per sq. in.	80 000	70 000	60 000
Yield Point, lb. per sq. in.	0.45 tens. str.	0.45 tens. str.	0.45 tens. str.
Elongation in 2 in., per cent	15	18	22
Reduction of area, "	20	25	30

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests.

10. (*a*) The test specimen for soft castings shall bend cold through 120 deg., and for medium castings through 90 deg., around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

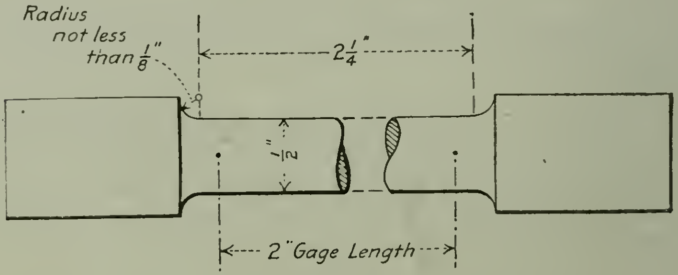
(*b*) Hard castings shall not be subject to bend test requirements.

Alternative Tests to Destruction.

11. In the case of small or unimportant castings, a test to destruction on three castings from a lot may, upon agreement

between the manufacturer and the purchaser, be substituted for the tension and bend tests. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. Unless otherwise agreed upon between the manufacturer and the purchaser, a lot shall consist of all castings from one melt, in the same annealing charge.

Test Specimens. 12. (*a*) Sufficient test bars, from which the test specimens required in Section 13 (*a*) may be selected, shall be attached to castings weighing 500 lb. or over, when the design of the castings will permit. If the castings weigh less than 500 lb., or are of such a design that test bars cannot be attached, two test bars shall be cast to represent each melt; or the quality of the castings shall be determined by tests to destruction as specified in Section 11. All test bars shall be annealed with the castings they represent.



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*b*) The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be machined to 1 by $\frac{1}{2}$ in. in section with corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests. 13. (*a*) One tension and one bend test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 9 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 14. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot not more than twice and retests shall be as specified in Sections 9 and 10.

IV. WORKMANSHIP AND FINISH.

Workmanship. 15. The castings shall substantially conform to the sizes and shapes of the patterns, and shall be made in a workmanlike manner.

Finish. 16. (*a*) The castings shall be free from injurious defects.

(*b*) Minor defects which do not impair the strength of the castings may, with the approval of the purchaser or his representative, be welded by an approved process. The defects shall first be cleaned out to solid metal; and after welding, the castings shall be annealed, if specified by the purchaser or his representative.

(*c*) Castings shall not be offered for inspection if covered with paint, rust, or any other substance to such an extent as to hide defects.

V. INSPECTION AND REJECTION.

Inspection. 17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 8 shall be reported within five working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 19. Samples tested in accordance with Section 8, which represent rejected castings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

VI. SPECIAL REQUIREMENTS FOR CASTINGS FOR SHIPS.

Castings for Ships. 20. In addition to the preceding requirements, castings for ships, when so specified, shall conform to the following requirements:

Heat Treatment. 21. All castings shall be annealed.

Number of Tests. 22. (*a*) One tension and one bend test shall be made from each of the following castings: stern frames, stern posts, twin screw spectacle frames, propeller shaft brackets, rudders, steering quadrants, tillers, stems, anchors, and other castings when specified.

(*b*) When a casting is made from more than one melt, four tension and four bend tests shall be made from each casting.

Percussion Tests. 23. (*a*) A percussion test shall be made on each of the following castings: stern frames, stern posts, twin screw spectacle frames, propeller shaft brackets, rudders, steering quadrants, tillers, stems, anchors, and other castings when specified.

(*b*) For this test, the casting shall be suspended by chains and hammered all over with a hammer of a weight approved by the purchaser or his representative. If cracks, flaws, defects, or weakness appear after such treatment, the casting will be rejected.

VII. SPECIAL REQUIREMENTS FOR CASTINGS FOR RAILWAY ROLLING STOCK.

Castings for Railway Rolling Stock. 24. Castings for railway rolling stock, when so specified, shall conform to the requirements for Class B castings, Sections 1 to 19, inclusive, except that check analyses made in accordance with Section 8 (*b*) shall conform to the requirements as to phosphorus and sulfur specified in Section 6.

STANDARD SPECIFICATIONS
FOR
LAP-WELDED AND SEAMLESS STEEL BOILER TUBES FOR LOCOMOTIVES.

Serial Designation: A 28 – 21.

These specifications are issued under the fixed designation A 28; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1916, 1918, 1921.

Material Covered. 1. These specifications cover lap-welded and seamless steel boiler tubes, boiler flues, superheater pipes, safe ends and arch tubes for locomotives.

I. MANUFACTURE.

Process. 2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.08 – 0.18	per cent
Manganese	0.30 – 0.60	"
Phosphorus	not over 0.04	"
Sulfur	" " 0.045	"

Check Analyses. 4. (*a*) Analyses of two tubes in each lot of 250 or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analyses shall be taken from several points around each tube.

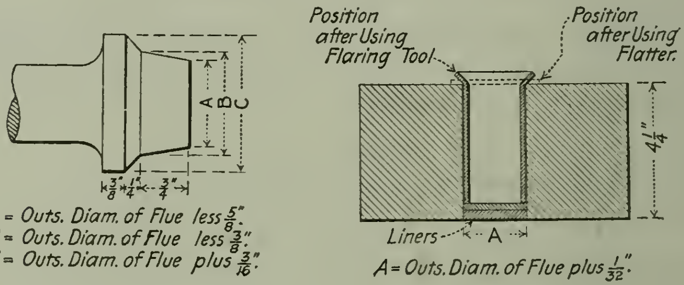
(*b*) If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

III. PHYSICAL PROPERTIES AND TESTS.

Flange Tests. 5. (*a*) For all tubes 6 in. or under in diameter and having a thickness less than 9 per cent of the outside diameter, a test specimen shall have a flange turned over at right angles to the body of the tube without showing cracks or flaws. This flange, as measured from the outside diameter of the tube, shall not be less than 15 per cent of the outside diameter, but the flange shall in no case exceed $\frac{1}{2}$ in. in width.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Flattening Tests. 6. (*a*) For all tubes, except tubes and superheater pipes on which the flange test is not required, a test specimen 3 in. in length shall stand flattening between parallel plates until the distance between the plates is not over three times the wall thickness, without showing cracks or flaws. For lap-welded tubes, care shall be taken that the weld is not located at the point of maximum bend.


A
B
C
3/8"
1/4"
3/4"
A = Outs. Diam. of Flue less 5/8".
B = Outs. Diam. of Flue less 3/8".
C = Outs. Diam. of Flue plus 3/16".
Position after Using Flaring Tool
Position after Using Flatter.
4 1/4"
Liners
A
A = Outs. Diam. of Flue plus 1/32".

Flaring Tool.

Die Block.

FIG. 1.

(*b*) For tubes and superheater pipes on which the flange test is not required, a test specimen 3 in. in length shall stand flattening between parallel plates until the distance between the plates is not over four times the wall thickness, without showing cracks or flaws.

Crush Tests. 7. (*a*) For all tubes except superheater pipes, a test specimen $2\frac{1}{2}$ in. in length shall stand crushing longitudinally until the outside folds are in contact, without showing cracks or flaws.

(*b*) For superheater pipes, a test specimen $2\frac{1}{2}$ in. in length shall stand crushing longitudinally down to $1\frac{1}{4}$ in., without showing cracks or flaws.

Hydrostatic Tests. 8. Tubes under 5 in. in diameter shall stand an internal hydrostatic pressure of 1000 lb. per sq. in., and tubes 5 in. or over in diameter shall stand an internal hydrostatic pressure of 800 lb. per sq. in.; provided that the fiber stress does not exceed

16,000 lb. per sq. in., in which case the test pressure shall be determined by the following formula:

$$P=\frac{32,000\ t}{D}$$

in which P = the pressure in pounds per square inch, t = the thickness of wall in inches, and D = the inside diameter of tube in inches. Lap-welded tubes shall be struck near both ends, while under the test pressure, with a 2-lb. steel hand hammer or the equivalent.

Test Specimens.

9. (*a*) Test specimens shall consist of sections cut from tubes selected by the inspector representing the purchaser from the lot offered for shipment. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests.

10. One of each of the physical tests specified shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

Retests.

11. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified in Sections 5, 6 or 7, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

IV. STANDARD WEIGHTS.

Standard Weights.

12. The standard weights for tubes of various outside diameters and thicknesses, are as indicated in Table I.

Permissible Variations.

13. (*a*) The weight of cold-drawn seamless tubes shall vary not more than 5 per cent from that specified in Table I.

(*b*) The weight of hot-finished tubes under $3\frac{1}{2}$ in. outside diameter shall vary not more than 5 per cent above or below that specified in Table I. Tubes $3\frac{1}{2}$ in. and larger in outside diameter may vary $2\frac{1}{2}$ per cent below and $7\frac{1}{2}$ per cent above that specified.

V. WORKMANSHIP AND FINISH.

Workmanship.

14. (*a*) Finished tubes $3\frac{1}{2}$ in. or under in outside diameter shall be circular within 0.02 in, and the mean outside diameter shall vary not more than 0.015 in. from the size ordered. For tubes over $3\frac{1}{2}$ in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter.

(*b*) The thickness of cold-drawn tubes at any point shall vary not more than 1 gage above or 1 gage below that specified.

(*c*) The thickness of hot-finished tubes at any point shall

TABLE I.—STANDARD WEIGHTS.

LAP-WELDED AND SEAMLESS STEEL BOILER TUBES FOR LOCOMOTIVES.

INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.													
B. w. g.	In.	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{1}{2}$	6
13	0.095	1.679	1.806	1.932	2.186	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	1.910	2.055	2.201	2.492	2.783	3.365	.....	.....	.....	.....	.....	.....	.....	.....
11	0.120	2.089	2.249	2.409	2.729	3.050	3.691	4.331	.....	.....	.....	.....	.....	.....	.....
10	0.134	2.312	2.491	2.670	3.028	3.386	4.101	4.817	5.532	.....	.....	.....	.....	.....	.....
9	0.148	2.532	2.729	2.927	3.322	3.717	4.508	5.298	6.088	6.879	7.669	8.064	8.262	8.459	9.250
8	0.165	.....	.....	.....	.....	4.114	4.995	5.877	6.758	7.639	8.520	8.960	9.181	9.401	10.282
7	0.180	.....	....	.....	.....	4.460	5.421	6.382	7.343	8.304	9.266	9.746	9.987	10.227	11.188

SMALL SUPERHEATER PIPES.

SEAMLESS ONLY.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.											
B. w. g.	In.	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$
13	0.095	0.537	0.601	.....	.....	.....	.....	.....	.....	.....	.	....	.....
12	0.109	.....	.....	0.746	0.818	.....	.....	.....	.....	.....	.....	.....	.....
11	0.120	.....	.....	.....	.....	0.967	1.047	1.127	.....	.....	.....	...	...
10	0.134	.....	.....	.....	.....	.....	.....	.....	1.597	1.776	1.865	1	33
9	0.148	.....	.....	.....	.....	.....	.....	.....	1.741	1.939	2.038	2.13	2.334

not exceed two gages above or one gage below that specified, but in all cases the weight variation shall be within that specified in Paragraph 13 (*b*). In the case of boiler tubes that are expanded and swaged, the thickness of the expanded end may be 1½ gages lighter and the swaged end three gages heavier than the thickness specified.

(*d*) The length shall be not less, but may be 0.125 in. more than that ordered.

15. The finished tubes shall be free from injurious defects and distortion, and shall have a workmanlike finish. **Finish.**

VI. MARKING.

16. The name or brand of the manufacturer, the material from which it is made, and the pressure in pounds at which it was tested, shall be legibly stenciled on each tube. **Marking.**

VII. INSPECTION AND REJECTION.

17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tubes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Superheater pipes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. Tubes or superheater pipes which fail in any of the above operations will be rejected, and the manufacturer shall be notified.

19. Samples tested in accordance with Section 4, which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS
FOR
LAP-WELDED AND SEAMLESS STEEL AND WROUGHT-IRON BOILER TUBES FOR STATIONARY SERVICE.

Serial Designation: A 52 – 18.

These specifications are issued under the fixed designation A 52; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1915; Revised, 1918.

Material Covered.

1. These specifications cover lap-welded and seamless steel and wrought-iron boiler tubes, boiler flues, superheater pipes, safe ends and arch tubes for stationary service.

I. MANUFACTURE.

Process.

2. (*a*) Lap-welded tubes shall be made of open-hearth steel or knobbled, hammered charcoal iron.

(*b*) Seamless tubes shall be made of open-hearth steel.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. (*a*) The steel shall conform to the following requirements as to chemical composition:

Carbon	0.08 – 0.18	per cent
Manganese	0.30 – 0.60	"
Phosphorus	not over 0.04	"
Sulfur	" " 0.045	"

(*b*) Chemical analysis will not be required for charcoal-iron tubes.

Check Analyses.

4. (*a*) Analyses of two tubes in each lot of 250 steel tubes or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analyses shall be taken from several points around each tube.

(*b*) If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

III. PHYSICAL PROPERTIES AND TESTS.

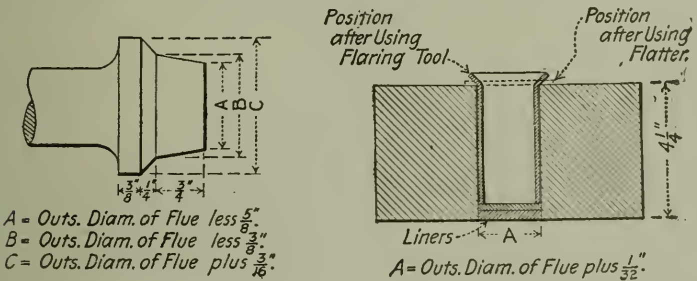
Flange Tests.

5. (*a*) For tubes not more than 6 in. in diameter having a thickness less than 10 per cent of the outside diameter, provided the thickness does not exceed No. 6 B.w.g., a test specimen not less than 4 in. in length shall have a flange turned over at right angles to the body of the tube without showing cracks or flaws. This flange, as measured from the outside diameter of the tube, shall not be less than 10 per cent of the outside diameter, provided that in no case shall the flange be less than ⅛ in. or greater than ½ in. in width. For all other tubes, the flange test is not required.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Flattening Tests.

6. A test specimen 3 in. in length shall stand flattening between parallel plates until the distance between the plates is not over five times the wall thickness, without showing cracks or flaws. For lap-welded tubes, the test shall be made with the weld at the point of maximum bend.


A
B
C
3/8"
1/4"
3/4"
A = Outs. Diam. of Flue less 5/8".
B = Outs. Diam. of Flue less 3/8".
C = Outs. Diam. of Flue plus 3/16".
Position after Using Flaring Tool
Position after Using Flatter
4 1/4"
Liners
A
A = Outs. Diam. of Flue plus 1/32".

Flaring Tool. Die Block.

FIG. 1.

Hydrostatic Tests.

7. Tubes under 5 in. in diameter shall stand an internal hydrostatic pressure of 1000 lb. per sq. in., and tubes 5 in. or over in diameter shall stand an internal hydrostatic pressure of 800 lb. per sq. in.; provided that the fiber stress does not exceed 16,000 lb. per sq. in., in which case the test pressure shall be determined by the following formula:

$$P = \frac{32,000\ t}{D}$$

in which P = the pressure in pounds per square inch, t = the thickness of wall in inches, and D = the inside diameter of tube in inches. Lap-welded tubes shall be struck near both ends,

TABLE I.—STANDARD WEIGHTS.

LAP-WELDED AND SEAMLESS STEEL BOILER TUBES FOR STATIONARY SERVICE.

INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

Thickness		Weight, lb. per ft. of Length. Outside Diameter, in.																						
B.w.g.	In.	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4½	5	5¼	5⅜	5½	6	7	8	9	10	11	12	13
13	0.095	1.679	1.932	2.186	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	1.910	2.201	2.492	2.783	3.074	3.365	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	0.120	2.089	2.409	2.729	3.050	3.370	3.691	4.011	4.331	4.652	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	0.134	2.312	2.670	3.028	3.386	3.743	4.101	4.459	4.817	5.175	5.532	6.248	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	0.148	2.532	2.927	3.322	3.717	4.112	4.508	4.903	5.298	5.693	6.088	6.879	7.669	8.064	8.262	8.459	.....	.....	.....	.....	.....	.....	.....	.....
8	0.165	.....	3.233	.....	4.114	4.555	4.995	5.436	5.877	6.317	6.758	7.639	8.520	8.960	9.181	9.401	10.282	12.044	13.807	.....	.....	.....	.....	.....
7	0.180	.....	.....	.....	4.460	4.940	5.421	5.901	6.382	6.863	7.343	8.304	9.266	9.746	9.987	10.227	11.188	13.110	15.033	16.955	.....	.....	.....	.....
6	0.203	.....	.....	.....	4.980	5.522	6.064	6.606	.....	.....	8.232	9.316	10.400	.....	.....	.....	12.568	14.736	16.904	19.072	21.240	.....	.....	.....
5	0.220	.....	.....	.....	5.357	5.944	6.531	7.119	.....	.....	.....	.....	11.231	.....	.....	.....	13.580	15.930	18.280	20.629	22.979	25.329	.....	.....
4½	0.220	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28.788	.....
4	0.238	.....	.....	.....	5.749	6.385	7.020	7.656	.....	.....	.....	.....	.....	.....	.....	.....	14.646	17.188	19.730	22.271	24.813	27.355	.....	32.439
½	0.2485	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	31.188	.....
3	0.250	.....	4.815	5.507	6.198	6.890	7.582	8.273	8.965	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.179	26.945	29.711	.....	35.243
2½	0.2715	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.008	.....
2	0.284	.....	.....	.....	6.721	.....	8.238	8.996	9.754	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29.470	32.503	.....	38.569

NOTE.—Seamless tubes are at present not available above 6 in. in outside diameter.

TABLE I.—STANDARD WEIGHTS.—*Continued.*

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.																						
B. w. g.	In.	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{2}$	5	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{1}{2}$	6	7	8	9	10	11	12	13
$1\frac{1}{2}$	0.292	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	36.512	.....
1	0.300	.....	.....	.....	7.048	7.849	8.650	9.451	10.252	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.283	.....	40.69
$\frac{1}{2}$	0.320	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	39.918	.....
0	0.340	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	45.971

NOTE.—Seamless tubes are at present not available above 6 in. in outside diameter.

SMALL SUPERHEATER PIPES.

SEAMLESS ONLY.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.											
B. w. g.	In.	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$
14	0.383	0.480	0.535	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	0.095	0.537	0.601	0.664	0.727	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	.....	.....	0.746	0.818	0.891	.....	.....	.....	.....	.....	.....	.....
11	0.120	.....	.....	.....	0.887	0.967	1.047	1.127	.....	.....	.....	.....	.....
10	0.134	.....	.....	.....	.....	1.060	1.149	1.239	1.597	1.776	1.865	1.954	2.133
9	0.148	.....	.....	.....	.....	.....	1.247	1.346	1.741	1.939	2.038	2.138	2.334
8	0.165	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.352	.....

while under the test pressure, with a 2-lb. steel hand hammer or the equivalent.

Etch Tests for Charcoal-Iron Tubes.[1] 8. A cross-section of charcoal-iron tube may be turned or ground to a true surface, polished free from dirt or cracks, and etched until the soft parts are sufficiently dissolved for the iron tube to show a decided ridged surface, with the weld very distinct, while a steel tube would show a homogeneous surface.

Test Specimens. 9. (*a*) All test specimens shall be taken from tubes before being cut to finished lengths and shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests. 10. All tubes shall be subjected to the hydrostatic test. One of each of the physical tests specified shall be made from each of two tubes in each lot of 250 or less.

Retests. 11. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified in Sections 5 or 6, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

IV. STANDARD WEIGHTS.

Standard Weights. 12. The standard weights for tubes of various outside diameters and thicknesses, are as indicated in Table I.

V. WORKMANSHIP AND FINISH.

Workmanship. 13. (*a*) Finished tubes 3½ in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 3½ in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter.

(*b*) All tubes shall be gaged with a Birmingham wire gage and shall not be less than the thickness specified, except that tubes will be accepted on which the gage will go on tightly at the thinnest point.

(*c*) The length shall not be less, but may be 0.125 in. more than that ordered.

Finish. 14. The finished tubes shall be free from injurious defects and distortion, and shall have a workmanlike finish.

VI. MARKING.

Marking. 15. The name or brand of the manufacturer, the material from which it is made, whether steel or charcoal iron, and the pressure in pounds at which it was tested, shall be legibly stenciled on each tube.

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[1] A solution of two parts water, one part HCl (sp. gr. 1.20) and one part H_2SO_4 (sp. gr. 1.84) is recommended for the etch test.

VII. INSPECTION AND REJECTION.

16. Inspection and all tests except check analyses shall be made at the place of manufacture. The manufacturer shall furnish the purchaser of each lot of tubes a statement of the kind of material of which the tubes are made, and that the tubes have been tested and have met all the requirements of the specifications. **Inspection.**

17. Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Superheater pipes when properly manipulated shall stand all forging, welding and bending operations necessary for application without developing defects. Tubes or superheater pipes which fail in any of the above operations will be rejected, and the manufacturer shall be notified. **Rejection.**

APPENDIX.

The following information, reprinted, by permission, from paragraphs 21 and 22 of the 1918 edition of the Boiler Code of the American Society of Mechanical Engineers, is appended to these specifications as information of possible value to users of the specifications:

Maximum Allowable Working Pressures for Water Tubes in Water-Tube and Fire-Tube Boilers.

Tubes for Water-Tube Boilers.—The maximum allowable working pressures for tubes used in water-tube boilers shall be, for the various diameters and gages measured by Birmingham wire gage, as given in the accompanying table.

Tubes for Fire-Tube Boilers.—The minimum thicknesses of tubes used in fire-tube boilers, measured by Birmingham wire gage, for maximum allowable working pressure not exceeding 175 lb. per sq. in. shall be as follows:

Diameter 1 in. or over, but less than 2½ in.	No. 13 B.w.g.
Diameter 2½ in. or over, but less than 3¼ in.	No. 12 B.w.g.
Diameter 3¼ in. or over, but less than 4 in.	No. 11 B.w.g.
Diameter 4 in. or over, but less than 5 in.	No. 10 B.w.g.
Diameter 5 in.	No. 9 B.w.g.

For each increase of one gage in thickness the maximum allowable working pressure will be increased by 200 lb. divided by the diameter of the tube in inches.

MAXIMUM ALLOWABLE WORKING PRESSURES FOR TUBES FOR WATER-TUBE BOILERS.

FOR DIFFERENT DIAMETERS AND GAGES OF TUBES.

Outside Diam. of Tube, in.	Birmingham Wire Gage.												
D	17 $t=0.058$	16 $t=0.065$	15 $t=0.072$	14 $t=0.083$	13 $t=0.095$	12 $t=0.109$	11 $t=0.120$	10 $t=0.134$	9 $t=0.148$	8 $t=0.165$	7 $t=0.180$	6 $t=0.203$	5 $t=0.220$
$\frac{1}{2}$	434	686	938	1334	...	...	...	...	...	...	...	...	...
$\frac{3}{4}$	206	374	542	806	1094	...	...	...	..	...	...	...	...
1	...	218	344	542	758	1010	...	...	...	...	...	...	...
$1\frac{1}{8}$	...	166	278	454	646	870	1046	...	...	...	...	...	...
$1\frac{1}{4}$	...	124	225	383	557	758	916	1118	...	...	...	...	...
$1\frac{1}{2}$	...	...	146	278	422	590	722	890	1058	...	...	...	...
$1\frac{3}{4}$	...	...	...	203	326	470	583	727	871	1046	...	...	...
2	...	...	...	146	254	380	479	605	731	884	1019	...	...
$2\frac{1}{4}$	...	...	...	...	198	310	398	510	622	758	878	1062	...
$2\frac{1}{2}$	...	...	...	...	153	254	333	434	535	657	765	931	1053
$2\frac{3}{4}$	...	...	...	...	117	208	280	372	464	575	673	824	935
3	...	...	...	...	...	170	236	320	404	506	596	734	836
$3\frac{1}{4}$	...	...	...	...	...	...	199	276	354	448	531	658	752
$3\frac{1}{2}$	...	...	...	...	...	...	167	238	310	398	475	594	681
$3\frac{3}{4}$	...	...	...	...	...	...	139	206	273	355	427	537	619
4	...	...	...	...	...	...	...	178	240	317	385	488	565
$4\frac{1}{2}$	...	...	...	...	...	...	...	...	186	254	314	406	474
5	...	...	...	...	...	...	...	...	142	204	258	340	402

$$P=\left(\frac{t-0.039}{D}\right)18000-250$$

Where P = Maximum allowable working pressure, lb. per sq. in.
t = Thickness of tube wall, in.
D = Outside diameter of tube, in.

NOTE.—Maximum allowable working pressures for superheater tubes shall be the same as for boiler tubes.

STANDARD SPECIFICATIONS
FOR
WELDED AND SEAMLESS STEEL PIPE.

Serial Designation: A 53 – 21.

These specifications are issued under the fixed designation A 53; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1915; Revised, 1918, 1921.

Material Covered.

1. These specifications cover "standard" and "extra strong" welded and seamless steel pipe, but not "double extra strong" pipe. Pipe ordered under these specifications are intended for bending, flanging and other special purposes.

I. MANUFACTURE.

Process.

2. (*a*) The steel for welded pipe shall be of soft weldable quality made by the Bessemer or by the open-hearth process. The steel for seamless pipe shall be made by the open-hearth process.

(*b*) Welded pipe 3 in. or under in nominal diameter may be butt-welded, unless otherwise specified. Welded pipe over 3 in. in nominal diameter shall be lap-welded.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. Open-hearth steel shall conform to the following requirement as to chemical composition:

Phosphorus........................not over 0.05 per cent

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

4. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

	Welded		Seamless
	Bessemer.	Open-hearth.	Open-hearth.
Tensile strength, lb. per sq. in..	50 000	45 000	48 000
Yield point, " " .	30 000	25 000	26 500
Elongation in 8 in., per cent...	18	20	18

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Hydrostatic Tests.

5. (*a*) Welded pipe shall be tested at the mill to the hydrostatic pressures specified in Table I.

(*b*) Seamless pipe shall be tested at the mill to hydrostatic pressures not exceeding that required by the formula:

$$P = \frac{2\,S\,t}{D}$$

in which P = pressure in pounds per square inch; S = allowable fiber stress = 16,000 lb. per sq. in.; t = thickness of wall in fnches; and D = inside diameter in inches.

Flattening Tests.

6. (*a*) For lap-welded pipe over 2 in. in diameter, a section of pipe 6 in. long shall be flattened between parallel plates until the distance between the plates is one-third the outside diameter of the pipe with the weld located 45 deg. from the line of direction of the applied force, without developing cracks.

(*b*) For butt-welded pipe over 2 in. in diameter, a section of pipe 6 in. long shall be flattened between parallel plates until the distance between the plates is 60 per cent of the outside diameter of the pipe with the weld located 45 deg. from the line of direction of the applied force, without developing cracks.

Bend Tests.

7. For pipe 2 in. or under in diameter, a sufficient length of pipe shall withstand being bent cold through 90 deg. around a cylindrical mandrel the diameter of which is 12 times the nominal diameter of the pipe, without developing cracks at any portion and without opening the weld.

Test Specimens.

8. (*a*) Test specimens shall consist of sections cut from a pipe. They shall be smooth on the ends and free from burrs.

(*b*) Tension test specimens shall be longitudinal.

(*c*) All specimens shall be tested cold.

Number of Tests.

9. One of each of the tests specified in Sections 4, 6, and 7, may be made on a length in each lot of 500 or less, of each size. Each length shall be subjected to the hydrostatic test.

Retests.

10. If the results of the physical tests of any lot do not conform to the requirements specified in Sections 4, 6, and 7, retests of two additional pipes shall be made, each of which shall conform to the requirements specified.

IV. STANDARD WEIGHTS.

Standard Weights.

11. (*a*) The standard weights for pipe of various inside diameters are given in Table II.

(*b*) Nipples shall be cut from pipe of the same weight and quality as described in these specifications.

Permissible Variations.

12. The weight of the pipe shall not vary more than 5 per cent from that specified in Table II.

Lengths. 13. Unless otherwise specified, pipe shall be furnished as to lengths in accordance with the following regular practice:

(*a*) Standard pipe shall be in random lengths of 16 to 22 ft., but not more than 5 per cent of the total number of lengths may be "jointers," which are two pieces coupled together.

TABLE I.—HYDROSTATIC PRESSURES FOR WELDED STEEL PIPE.
(Pressures Expressed in Pounds per Square Inch)
(BLACK AND GALVANIZED)

Size, (Nominal Inside Diameter), in.	"Standard" Pipe.			"Extra Strong" Pipe.		
	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Butt-Weld.	Lap-Weld.	Weight of Pipe per Linear Foot, Plain Ends, lb.	Butt-Weld.	Lap-Weld.
$\frac{1}{8}$	.....	700	....	.....	700	....
$\frac{1}{4}$	.....	700	....	.....	700	....
$\frac{3}{8}$	.....	700	....	.....	700	....
$\frac{1}{2}$	.....	700	....	.....	700	....
$\frac{3}{4}$	.....	700	....	.....	700	....
1	.....	700	....	.....	700	....
$1\frac{1}{4}$	.....	700	1000	.....	1500	2500
$1\frac{1}{2}$	.....	700	1000	.....	1500	2500
2	.....	700	1000	.....	1500	2500
$2\frac{1}{2}$	.....	800	1000	.....	1500	2000
3	.....	800	1000	.....	1500	2000
$3\frac{1}{2}$	.....	...	1000	.....	....	2000
4	.....	...	1000	.....	....	2000
$4\frac{1}{2}$	.....	...	1000	.....	....	1800
5	.....	...	1000	.....	....	1800
6	.....	...	1000	.....	....	1800
7	.....	...	1000	.....	....	1500
8	25.00	...	800	.....	....	....
8	28.81	...	1000	43.39	....	1500
9	34.19	...	900	48.73	....	1200
10	32.00	...	600	.....	....	....
10	35.00	...	700	.....	....	....
10	41.13	...	900	54.74	....	1000
11	46.25	...	800	60.08	....	1000
12	45.00	...	600	.....	....	....
12	50.71	...	800	65.42	....	1000

For pipes over 12 in. in inside diameter, the test pressures should be calculated by the formula $P = \frac{2\,St}{D}$ in which P = pressure in pounds per square inch; S = fiber stress = 12,000 lb. per sq. in.; t = thickness of wall in inches; D = inside diameter in inches.

When ordered with plain ends, 5 per cent may be in lengths of 12 to 16 ft.

(*b*) Extra strong pipe shall be in random lengths of 12 to 22 ft. Five per cent may be in lengths of 6 to 12 ft.

TABLE II.—STANDARD WEIGHTS AND DIMENSIONS OF WELDED AND SEAMLESS STEEL PIPE.

(BLACK AND GALVANIZED)

Size (Nominal Inside Diameter), in.	"Standard" Pipe.				"Extra Strong" Pipe.	
	Outside Diameter, in.	Number of Threads per Inch.	Thickness, in.	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.
$\frac{1}{8}$.........	0.405	27	0.068	0.25	0.095	0.31
$\frac{1}{4}$.........	0.540	18	0.088	0.43	0.119	0.54
$\frac{3}{8}$.........	0.675	18	0.091	0.57	0.126	0.74
$\frac{1}{2}$.........	0.840	14	0.109	0.85	0.147	1.09
$\frac{3}{4}$.........	1.050	14	0.113	1.13	0.154	1.47
1...........	1.315	11$\frac{1}{2}$	0.133	1.68	0.179	2.17
1$\frac{1}{4}$.........	1.660	11$\frac{1}{2}$	0.140	2.28	0.191	3.00
1$\frac{1}{2}$.........	1.900	11$\frac{1}{2}$	0.145	2.73	0.200	3.63
2...........	2.375	11$\frac{1}{2}$	0.154	3.68	0.218	5.02
2$\frac{1}{2}$.........	2.875	8	0.203	5.82	0.276	7.66
3...........	3.500	8	0.216	7.62	0.300	10.25
3$\frac{1}{2}$.........	4.000	8	0.226	9.20	0.318	12.51
4...........	4.500	8	0.237	10.89	0.337	14.98
4$\frac{1}{2}$.........	5.000	8	0.247	12.64	0.355	17.61
5...........	5.563	8	0.258	14.81	0.375	20.78
6...........	6.625	8	0.280	19.19	0.432	28.57
7...........	7.625	8	0.301	23.77	0.500	38.05
*8...........	8.625	8	0.277	25.00	.....	.....
8...........	8.625	8	0.322	28.81	0.500	43.39
9...........	9.625	8	0.342	34.19	0.500	48.73
*10...........	10.750	8	0.279	32.00	.....	.....
*10...........	10.750	8	0.307	35.00	.....	.....
10...........	10.750	8	0.365	41.13	0.500	54.74
11...........	11.750	8	0.375	45.25	0.500	60.08
*12...........	12.750	8	0.330	45.00	.....	.....
12...........	12.750	8	0.375	50.71	0.500	65.42

* Unless specifically stated on the order the lighter weights will not be furnished. Weights given in the table are for pipes up to and including 12 in. in nominal inside diameter, with threaded ends and couplings; sizes larger than those shown in the table are measured by the outside diameter and will be furnished with plain ends unless otherwise specified; for such sizes it will be necessary to accept Manufacturers' weights or calculate the weights on the basis of one cubic inch of steel weighing 0.2833 lb.

V. WORKMANSHIP AND FINISH.

Workmanship. 14. For pipe $1\frac{1}{2}$ in. or under in inside diameter, the outside diameter at any point shall not vary more than $\frac{1}{64}$ in. over nor more than $\frac{1}{32}$ in. under the standard size. For pipe 2 in. or over in inside diameter, the outside diameter shall not vary more than 1 per cent over or under the standard size.

Ends. 15. Unless otherwise specified, pipe shall conform to the following regular practice:

(*a*) Each end of standard welded pipe shall be threaded.

(*b*) Extra strong welded pipe, and standard and extra strong seamless pipe shall be furnished with plain ends.

Threads. (*c*) All threads shall be in accordance with the American Standard[1] and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed a maximum of one and one-half turns either way.

Couplings. (*d*) Each length of threaded pipe shall be provided with one coupling, having clean-cut threads of such a pitch diameter as to make a tight joint. Couplings may be made of wrought iron or steel.

Finish. 16. The finished pipe shall be reasonably straight and free from injurious defects. All burrs at the ends of the pipe shall be removed.

VI. INSPECTION AND REJECTION.

Inspection. 17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, free of charge, all reasonable facilities to satisfy him that the pipe are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 18. Each length of pipe which develops injurious defects in shop working or application will be rejected, and the manufacturer shall be notified.

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[1] A complete description of the American Standard Pipe Thread is contained in the Pipe Thread Standard prepared under the sponsorship of the American Gas Association and the American Society of Mechanical Engineers and approved as American Standard by the American Engineering Standards Committee.

STANDARD SPECIFICATIONS
FOR
AUTOMOBILE CARBON AND ALLOY STEELS.

Serial Designation: A 29-21.

These specifications are issued under the fixed designation A 29; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1915, 1916, 1918, 1921.

Basis of Purchase.

1. Automobile steels shall be purchased on the basis of the requirements as to chemical composition specified in Sections 5, 6 and 7. Requirements as to physical properties have been omitted for all steels except castings, because the majority of automobile steels, except castings, are either worked or given special heat treatments by the purchaser.. It is recommended that tension and bend tests shall be specified for the material as shipped, whenever it is practicable to do so. When physical requirements are specified, requirements as to carbon shall be omitted.

Steel Castings

2. The Standard Specifications for Steel Castings, Class B (Serial Designation: A 27), of the American Society for Testing Materials, shall govern the purchase of automobile steel castings.

I. MANUFACTURE.

Process.

3. The steels may be made by one or more of the following processes: open-hearth, crucible or electric furnace; except that screw stock shall be made by the Bessemer or the open-hearth processes as specified.

Discard.

4. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

5. The steels shall conform to the requirements as to chemical composition specified in Tables I to VII, appended to these specifications, and which are entitled as follows:

TABLE.	TITLE.
I........	Automobile Carbon Steels.
II.......	Automobile Nickel Steels.
III......	Automobile Nickel-Chromium Steels.

TABLE.	TITLE.
IV.......	**Automobile Chromium Steels.**
V........	**Automobile Chromium-Vanadium Steels.**
VI......	Automobile Chromium-Tungsten Steels.
VII......	**Automobile Silico-Manganese Steels.**

Ladle Analyses.

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Tables I to VII. This analysis shall be made from drillings taken at least ¼ in. beneath the surface of a test ingot obtained during the pouring of the melt, and in as sound metal as possible. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Tables I to VII.

Check Analyses.

7. (*a*) Analyses may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Tables I to VII.

(*b*) Drillings for analyses of bars, billets, or other regular shapes shall be taken parallel to the axis, at any point midway between the center and surface.

(*c*) Drillings for analyses may be taken from broken tension or bend test specimens, if physical requirements are specified.

(*d*) Drillings or cuttings for analyses of irregularly shaped pieces for which no physical requirements are specified, shall be taken from both the thickest and the thinnest sections. Surface drillings shall be discarded.

(*e*) Wire, tubing, sheets, and rods less than 1¼ in. in thickness, shall be sampled through or across the entire section.

III. PHYSICAL PROPERTIES AND TESTS.

Physical Properties.

8. If physical requirements are specified, the following Sections 9 to 13 shall form a part of the modified specifications.

Yield Point.

9. The yield point shall be determined by the drop of the beam of the testing machine.

Elastic Limit.

10. The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase.

The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

Bend Tests.

11. The bend test shall be made cold.

Test Specimens.

12. (*a*) Tension and bend test specimens shall be taken from the rolled or forged material; except that in the case of irregularly shaped forgings, they may be taken from a full-size prolongation. Specimens shall not be annealed or otherwise treated, except as specified in Paragraph (*b*).

(*b*) Tension and bend test specimens for material which is to be annealed or otherwise treated before use shall be cut, for rolled material, from properly annealed or similarly treated short lengths of the full section of the piece, and for forged material from the treated forgings.

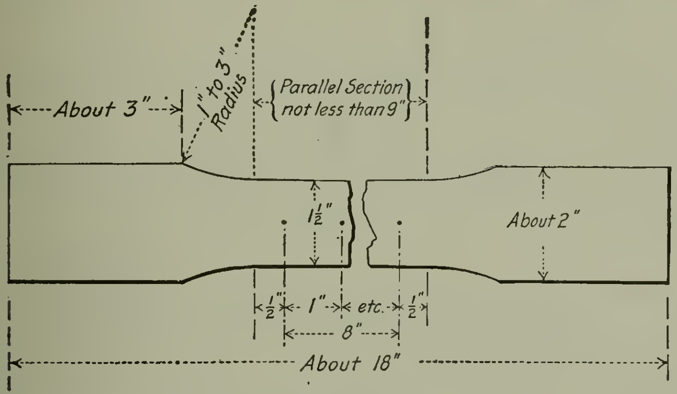


FIG. 1.

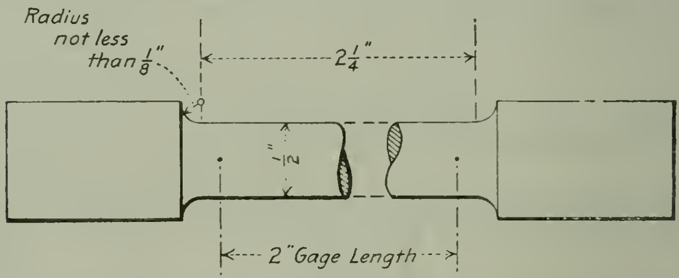
(*c*) Tension and bend test specimens for plates and shapes shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Tension and bend test specimens for rolled bars and forgings of uniform cross-section $1\frac{1}{2}$ in. or under in thickness or diameter, may be of the full-size section of material as rolled or forged, or may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in. Tension test specimens shall be of 8-in. gage length.

(*e*) The axis of tension and bend test specimens for rolled bars and forgings of uniform cross-section over $1\frac{1}{2}$ in. in thickness or diameter, and for forgings of irregular sections, when practicable, shall be located at any point midway between the center and surface when solid, and at any point midway between the inner and outer surfaces of the wall when bored, and shall be parallel to the axis of the piece in the direction in which the metal is most drawn out. Tension test specimens shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be ½ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests.

13. (*a*) Unless otherwise specified by the purchaser, one tension and one bend test shall be made from each melt; except that if material rolled from one melt differs ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than ¾ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. FINISH.

Finish.

14. **The material shall be free from injurious defects and shall have a workmanlike finish.**

V. INSPECTION AND REJECTION.

Inspection.

15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 15 (*b*) shall be reported within ten working days from the receipt of samples.

(*b*) Material which shows injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 15(*b*), which represent rejected material, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TABLE I.—AUTOMOBILE CARBON STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over
0.10	0.05 – 0.15	0.45	0.30 – 0.60	0.045	0.05
0.20	0.15 – 0.25	0.45	0.30 – 0.60	"	"
0.25	0.20 – 0.30	0.65	0.50 – 0.80	"	"
0.35	0.30 – 0.40	0.65	0.50 – 0.80	"	"
0.45	0.40 – 0.50	0.65	0.50 – 0.80	"	"
0.95	0.90 – 1.05	0.35	0.25 – 0.50	0.04	"

SCREW STOCK.

GRADE.	CARBON.	MANGANESE.	PHOS.	SULF.
Bessemer................	0.08 – 0.16	0.60 – 0.80	0.09 – 0.13	0.075 – 0.15
Open-hearth..............	0.15 – 0.25	0.60 – 0.90	not over 0.06	0.075 – 0.15

The requirements for screw stock material cover a free-cutting steel suitable for high-speed screw machine work, leaving a smooth finish after machining.

STEEL CASTINGS, CLASS B.

As required for the chemical and physical properties. See Standard Specifications for Steel Castings (Serial Designation: A 27).

All values are expressed in per cent.

TABLE II.—AUTOMOBILE NICKEL STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	NICKEL.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.
0.15	0.10 – 0.20	0.65	0.50 – 0.80	0.04	0.045	3.50	3.25 – 3.75
0.20	0.15 – 0.25	"	" "	"	"	"	" "
0.30	0.25 – 0.35	"	" "	"	"	"	" "
0.35	0.30 – 0.40	"	" "	"	"	"	" "
0.40	0.35 – 0.45	"	" "	"	"	"	" "
0.45	0.40 – 0.50	"	" "	"	"	"	" "
....	not over 0.17	0.45	0.30 – 0.60	"	"	(a)	4.50 – 5.25

All values are expressed in per cent.

(a) When parts made of this steel are to be machined after carbonization, the nickel shall be close to the lower limit.

TABLE III.—AUTOMOBILE NICKEL-CHROMIUM STEELS.

WITH 1.25 PER CENT NICKEL.[1]

CARBON.		MANGANESE.		PHOS.	SULF.	NICKEL.		CHROMIUM.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.	Desired.	Permissible Range.
0.20	0.15–0.25	0.65	0.50–0.80	0.04	0.045	1.25	1.00–1.50	0.60	0.45–0.75
0.25	0.20–0.30	"	" "	"	"	"	" "	"	" "
0.30	0.25–0.35	"	" "	"	"	"	" "	"	" "
0.35	0.30–0.40	"	" "	"	"	"	" "	"	" "
0.40	0.35–0.45	"	" "	"	"	"	" "	"	" "
WITH 1.75 PER CENT NICKEL.									
0.20	0.15–0.25	0.45	0.30–0.60	0.04	0.04	1.75	1.50–2.00	1.10	0.90–1.25
0.30	0.25–0.35	"	" "	"	"	"	" "	"	" "
0.40	0.35–0.45	"	" "	"	"	"	" "	"	" "
0.50	0.45–0.55	"	" "	"	"	"	" "	"	" "
WITH 3.00 PER CENT NICKEL.									
0.15	0.10–0.20	0.60	0.45–0.75	0.04	0.04	3.00	2.75–3.25	0.80	0.60–0.95
0.35	0.30–0.40	"	" "	"	"	"	" "	"	" "
0.50	0.45–0.55	"	" "	"	"	"	" "	"	" "
WITH 3.50 PER CENT NICKEL.									
0.20	0.15–0.25	0.45	0.30–0.60	0.04	0.04	3.50	3.25–3.75	1.50	1.25–1.75
0.30	0.25–0.35	"	" "	"	"	"	" "	"	" "
0.40	0.35–0.45	"	" "	"	"	"	" "	"	" "

All values are expressed in per cent.

[1] Another type of the five grades of 1.25 per cent Nickel Steel is available with chromium 0.30 desired, permissible range 0.15-0.45.

TABLE IV.—AUTOMOBILE CHROMIUM STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	CHROMIUM.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.
0.20	0.15 - 0.25	..... [a]	... [a]	0.04	0.045	0.75	0.60 - 0.80
0.40	0.35 - 0.45	...... [a]	..... [a]	"	"	"	" "
0.65	0.60 - 0.70	...... [a]	...... [a]	"	"	"	" "
1.00	0.95 - 1.10	0.35	0.20 - 0.50	0.03	0.03	1.35	1.20 - 1.50

[a] In these three grades the specified percentages of manganese and silicon may be either of the following: manganese, 0.35 desired (permissible range, 0.25 - 0.50) and silicon, not over 0.20; or manganese, 0.70 desired (permissible range, 0.60 - 0.80) and silicon, 0.15 - 0.50.

All values are expressed in per cent.

TABLE V.—AUTOMOBILE CHROMIUM-VANADIUM STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	CHROMIUM.		VANADIUM.	
Desired.	Permissible Range.	Desired.	Permissible Range	Not Over	Not Over	Desired.	Permissible Range.	Desired.	Not Under
0.20	0.15–0.25	0.65	0.50–0.80	0.04	0.04	0.95	0.80–1.10	0.18	0.15
0.25	0.20–0.30	"	" "	"	"	"	" "	"	"
0.30	0.25–0.35	"	" "	"	"	"	" "	"	"
0.35	0.30–0.40	"	" "	"	"	"	" "	"	"
0.40	0.35–0.45	"	" "	"	"	"	" "	"	"
0.45	0.40–0.50	"	" "	"	"	"	" "	"	"
0.50	0.45–0.55	"	" "	"	"	"	" "	"	"
0.95	0.90–1.05	0.35	0.20–0.45	0.03	0.03	"	" "	"	"

All values are expressed in per cent.

TABLE VI.—AUTOMOBILE CHROMIUM-TUNGSTEN STEELS.

Carbon.		Manganese, not over	Phosphorus, not over	Sulfur, not over	Chromium.		Tungsten.	
Desired.	Permissible Range.				Desired.	Permissible Range.	Desired.	Permissible Range.
0.60	0.50 - 0.70	0.30	0.035	0.035	3.50	3.00 - 4.00	13.00	12.00 - 15.00
0.60	0.50 - 0.70	0.30	0.035	0.035	3.50	3.00 - 4.00	16.00	15.00 - 18.00
0.60	0.50 - 0.70	0.30	0.035	0.035	0.75	0.50 - 1.00	1.75	1.50 - 2.00

TABLE VII.—AUTOMOBILE SILICO-MANGANESE STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	SILICON.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.
0.50	0.45–0.55	0.70	0.60–0.80	0.045[a]	0.045	1.95	1.80–2.10
0.60	0.55–0.65	0.60	0.50–0.70	0.045[a]	0.045	1.65	1.50–1.80

[a] Steels made by the acid process may contain 0.05 maximum phosphorus.

All values are expressed in per cent.

STANDARD SPECIFICATIONS
FOR
BOILER AND FIREBOX STEEL FOR LOCOMOTIVES.

Serial Designation: A 30 – 21.

These specifications are issued under the fixed designation A 30; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1901; Revised, 1909, 1912, 1913, 1914, 1916, 1918, 1921.

Material Covered. 1. These specifications cover two classes of steel for boilers for locomotives, namely: flange and firebox.

I. MANUFACTURE

Process. 2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

		Flange.	Firebox.
Carbon	for plates ¾ in. or under in thickness	....	0.12 – 0.25 per cent
	for plates over ¾ in. in thickness	....	0.12 – 0.30 "
Manganese	for plates ¾ in. or under in thickness	0.30 – 0.60	0.30 – 0.50 "
	for plates over ¾ in. in thickness	0.30 – 0.60	0.30 – 0.60 "
Phosphorus	Acid	not over 0.05	not over 0.04 "
	Basic	" " 0.04	" " 0.035 "
Sulfur		" " 0.05	" " 0.04 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The material shall conform to the following requirements as to tensile properties:

	FLANGE.	FIREBOX.
Tensile strength, lb. per sq. in.	55 000 – 65 000	52 000 – 62 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent. (See Section 7)	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentages of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in.

(*b*) For material $\frac{1}{4}$ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

Bend Tests.

8. The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Homogeneity Tests.

9. For firebox steel, a sample taken from a broken tension test specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. long, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about $\frac{1}{16}$ in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about $\frac{1}{4}$ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

Test Specimens.

10. (*a*) Tension test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimens shall be taken in the direction of the longitudinal axis of the ingot, and the transverse test specimens at right angles to that axis.

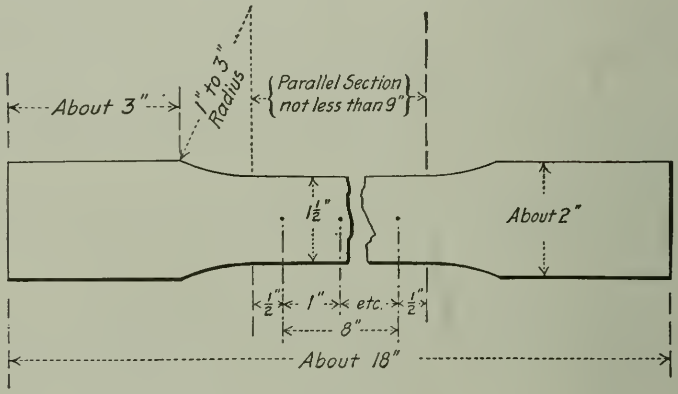


FIG. 1.

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

Number of Tests.

11. (*a*) One tension and one bend test shall be made from each plate as rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

12. The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108in., excl.	108 to 120in., excl.	120 to 132in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 '
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

V. FINISH.

Finish.

13. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking.

14. (*a*) The name or brand of the manufacturer, melt or slab number, class, and lowest tensile strength for its class specified in Section 6 (*a*), shall be legibly stamped on each plate. The melt or slab number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in Paragraph (*c*) so that the test specimens representing them may be identified. When more than one plate is sheared from a single slab or ingot, each shall be match-marked so that they may all be identified with the test specimen representing them.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

(*c*) Each match mark shall consist of two over-lapping circles each not less than 1½ in. in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

VII. INSPECTION AND REJECTION.

Inspection. 15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 17. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
BOILER RIVET STEEL.

Serial Designation: A 31 – 21.

These specifications are issued under the fixed designation A 31; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914, 1921.

A. Requirements for Rolled Bars.

I. MANUFACTURE.

Process.

1. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

2. The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30 – 0.50	per cent
Phosphorus	not over 0.04	"
Sulfur	" " 0.045	"

Ladle Analyses.

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

Check Analyses.

4. Analyses may be made by the purchaser from finished bars representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 2.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

5. (*a*) The bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45 000 – 55 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$, but need not exceed 30 per cent.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests. 6. (*a*) *Cold-bend Tests.*—The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

(*b*) *Quench-bend Tests.*—The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200° F.), and quenched at once in water the temperature of which is between 80 and 90° F., shall bend through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens. 7. (*a*) Test specimens shall be of the full diameter of bars as rolled.

(*b*) Tension and bend test specimens for rivet bars which have been cold drawn shall be normalized before testing.

Number of Tests. 8. (*a*) Two tension, two cold-bend, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN DIAMETER.

Permissible Variations. 9. The diameter of each bar shall not vary more than 0.01 in. from that specified.

V. WORKMANSHIP AND FINISH.

Workmanship. 10. The finished bars shall be circular within 0.01 in.

Finish. 11. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 12. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection. 13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt f samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

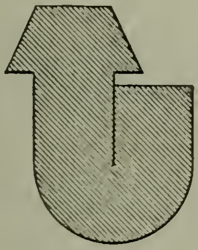

FIG. 1.

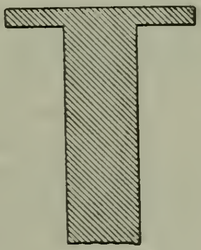

FIG. 2.

Rehearing 15. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Rivets.

VIII. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 16. The rivets, when tested, shall conform to the requirements as to tensile properties specified in Section 5, except that the elongation shall be measured on a gage length not less than four times the diameter of the rivet.

Bend Tests. 17. The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 1, without cracking on the outside of the bent portion.

Flattening Tests. 18. The rivet head shall flatten, while hot, to a diameter 2½ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges.

Number of Tests. 19. (*a*) When specified, one tension test shall be made from each size in each lot of rivets offered for inspection.

(*b*) Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

IX. WORKMANSHIP AND FINISH.

Workmanship. 20. The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

Finish. 21. The finished rivets shall be free from injurious defects.

X. INSPECTION AND REJECTION.

Inspection. 22. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 23. Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
COLD-DRAWN BESSEMER STEEL AUTOMATIC SCREW STOCK.

Serial Designation: A 32 – 14 T.

These specifications are issued under the fixed designation A 32; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1914.

Material Covered.

1. These specifications cover a free-cutting steel of yan specified section suitable for high-speed screw machine work, leaving a smooth finish after machining.

I. MANUFACTURE.

Process.

2. The steel shall be made by the Bessemer process, and shall be cold-rolled or cold-drawn or turned to size.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.08 – 0.16	per cent
Manganese	0.60 – 0.80	"
Phosphorus	0.09 – 0.13	"
Sulfur	0.075 – 0.15	"

Test Samples.

4. Samples for analysis shall be taken by machining off the entire cross-section of the bar, or by drilling parallel to the axis of the bar at any point midway between the center and surface with a drill not under $\frac{1}{2}$ nor over $\frac{3}{4}$ in. in diameter. Samples shall be clean, free from oil, uniformly fine and well mixed.

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations.

5. The variation from the specified diameter, or distance between parallel faces, and the allowable eccentricity shall not exceed the following limits:

PERMISSIBLE VARIATIONS.

Diameter.	Over-size.	Under-size.	Eccentricity.
Up to and including 0.3 in.	0	1% of diameter	0.5% of diameter
Over 0.3 in. to and including 1 in.	0	0.003 in.	0.0015 in.
Over 1 in. to and including 2½ in.	0	0.004 "	0.0020 "
Over 2½ in.	0	0.005 "	0.0025 "

IV. FINISH.

Finish. 6. The material shall be free from injurious defects and shall have a bright smooth surface.

V. INSPECTION AND REJECTION.

Inspection. 7. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 8. Material which fails to conform to the above specifications will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS

FOR

COLD-DRAWN OPEN-HEARTH STEEL AUTOMATIC SCREW STOCK.

Serial Designation: A 54–15.

These specifications are issued under the fixed designation A 54; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1915.

Material Covered.

1. These specifications cover a free-cutting steel of any specified section suitable for high-speed screw machine work, leaving a smooth finish after machining.

I. MANUFACTURE.

Process.

2. The steel shall be made by the open-hearth process, and shall be cold-rolled or cold-drawn or turned to size.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.15 – 0.25	per cent
Manganese	0.60 – 0.90	"
Phosphorus	not over 0.06	"
Sulfur	0.075 – 0.15	"

Test Samples.

4. Samples for analysis shall be taken by machining off the entire cross-section of the bar, or by drilling parallel to the axis of the bar at any point midway between the center and surface with a drill not under $\frac{1}{2}$ nor over $\frac{3}{4}$ in. in diameter. Samples shall be clean, free from oil, uniformly fine and well mixed.

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations.

5. The variation from the specified diameter, or distance between parallel faces, and the allowable eccentricity shall not exceed the following limits:

PERMISSIBLE VARIATIONS.

Diameter.	Over-size.	Under-size.	Eccentricity.
Up to and including 0.3 in.	0	1% of diameter	0.5% of diameter
Over 0.3 in. to and including 1 in.	0	0.003 in.	0.0015 in.
Over 1 in. to and including 2½ in.	0	0.004 "	0.0020 "
Over 2½ in.	0	0.005 "	0.0025 "

IV. FINISH.

Finish. 6. The material shall be free from injurious defects and shall have a bright smooth surface.

V. INSPECTION AND REJECTION.

Inspection. 7. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 8. Material which fails to conform to the above specifications will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
COMMERCIAL BAR STEELS.

Serial Designation: A 80 – 21.

These specifications are issued under the fixed designation A 80; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1920; ADOPTED IN AMENDED FORM, 1921.

Material Covered. 1. These specifications cover ordinary commercial carbon bar steels of grades considered to be in common use. The sections covered are rounds, squares and hexagons of all sizes, and flats not over 6 in. wide.

Basis of Purchase. 2. (*a*) Bars shall be hot-rolled or cold-finished, as specified.

(*b*) Cold-finished bars may be cold-rolled, cold-drawn, turned and polished, or turned and ground.

(*c*) The purchaser shall specify each grade desired by its grade designation or by its complete chemical limits.

I. MANUFACTURE.

Process. 3. The steel shall be made by the open-hearth or Bessemer process, as specified.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. The steel shall conform to the requirements as to chemical composition specified in Tables I and II for the respective grades.

Ladle Analyses. 5. An analysis of each melt shall be made by the manufacturer to determine the percentages of the elements specified. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements for the grade specified in Table I.

Check Analyses. 6. (*a*) Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt, or lot of ten tons, of Bessemer steel. The chemical composition thus determined shall conform to the requirements in Table I with the permissible variations in ranges and in maximum limits specified in Table II.

(*b*) Samples for analysis shall be taken by machining off the entire cross-section of the bar, or by drilling parallel to the axis of the bar at any point midway between the center and surface.

TABLE I.—GRADES AND CHEMICAL COMPOSITIONS.

GRADES.	Carbon, per cent.	Manganese, per cent.	Phosphorus, per cent.	Sulfur, per cent.
OPEN-HEARTH GRADES.				
Open-hearth Dead Soft	0.05 - 0.12	0.55 max.	0.05 max.	0.06 max.
Open-hearth Soft	0.08 - 0.18	0.55 "	0.05 "	0.06 "
Open-hearth 15–25 Carbon	0.15 - 0.25	0.60 "	0.05 "	0.06 "
Open-hearth 20–30 Carbon	0.20 - 0.30	0.70 "	0.05 "	0.06 "
Open-hearth 25–40 Carbon	0.25 - 0.40	0.70 "	0.05 "	0.06 "
Open-hearth 35–50 Carbon	0.35 - 0.50	0.70 "	0.05 "	0.06 "
BESSEMER GRADES.				
Bessemer Welding	0.12 and under	0.60 max.	0.115 max.	0.08 max.
Bessemer Soft	0.15 and under	0.70 "	0.115 "	....
Bessemer 15–25 Carbon	0.15 - 0.25	0.90 "	0.115 "	....
Bessemer 25–40 Carbon	0.25 - 0.40	0.90 "	0.115 "	....
Bessemer 35–50 Carbon	0.35 - 0.50	0.90 "	0.115 "	....
Bessemer 40–60 Carbon	0.40 - 0.60	1.00 "	0.115 "	....
SCREW STEEL GRADES.				
Bessemer Screw	0.08 - 0.16	0.60 - 0.80	0.09 - 0.13	0.075 - 0.15
Open-hearth Screw	0.15 - 0.25	0.60 - 0.90	0.06 max.	0.075 - 0.15

TABLE II.—VARIATIONS IN RANGES AND IN MAXIMUM LIMITS SPECIFIED IN TABLE I, PERMITTED ON CHECK ANALYSES.

GRADES.	Permissible Variations from Limits Specified in Table I.				
	Carbon.		Manganese.	Phosphorus.	Sulfur.
	Under Lower Limit.	Over Upper Limit.	Over Maximum.	Over Maximum.	Over Maximum.
OPEN-HEARTH GRADES.					
Dead Soft and Soft	....	0.03	0.05	0.01	0.01
15–25 Carbon	0.02	0.05	0.10	0.01	0.01
20–30 Carbon	0.03	0.06	0.10	0.01	0.01
25–40 Carbon	0.03	0.07	0.10	0.01	0.01
35–50 Carbon	0.03	0.08	0.10	0.01	0.01
BESSEMER GRADES.					
Welding and Soft	....	0.03	0.05	0.02	0.02
15–25 Carbon	0.02	0.05	0.10	0.02	....
25–40 Carbon	0.03	0.07	0.10	0.02	....
35–50 and 40–60 Carbon	0.05	0.08	0.10	0.02	....

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Permissible Variations.

7. The variation from the specified diameter, or distance between parallel faces, shall not exceed the limits specified in Table III.

IV. WORKMANSHIP AND FINISH.

Finish.

8. The material shall be free from injurious defects and shall have a workmanlike finish. Cold-finished bars shall have a bright smooth surface.

V. INSPECTION AND REJECTION.

Inspection. 9. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 10. Material which fails to conform to the above specifications will be rejected, and the manufacturer shall be notified.

TABLE III.—PERMISSIBLE VARIATIONS IN THE SIZES OF BARS.

HOT-ROLLED BARS.

Rounds, Squares and Hexagons: Sizes Specified.	Variations in Size, in.	
	Under.	Over.
Up to 1/2 in., incl.	0.007	0.007
Over 1/2 " 1 " "	0.010	0.010
" 1 " 2 " "	1/64	1/32
" 2 " 3 " "	1/32	3/64
" 3 " 5 " "	1/32	3/32
" 5 " 8 " "	1/16	1/8

Flats: Widths Specified.	Variations in Width, in.		Variations in Thickness, Under and Over, in., for Thicknesses Specified.			
	Under.	Over.	3/16 in. or Under.	Over 3/16 to 1/2 in., incl.	Over 1/2 to 1 in., incl.	Over 1 to 2 in., incl.
Up to 1 in., incl.	1/64	1/32	0.006	0.008	0.010	......
Over 1 " 2 " "	1/32	3/64	0.008	0.012	0.015	1/32
" 2 " 4 " "	3/64	1/16	0.010	0.015	0.020	1/32
" 4 " 6 " "	1/16	3/32	0.010	0.015	0.020	1/32

COLD-FINISHED BARS.

Sizes Specified.	Variations in Size, in.					
	Rounds and Hexagons.		Squares.		Flats: Width and Thickness.	
	Under.	Over.	Under.	Over.	Under.	Over.
Up to 0.3 in. incl.	1% of diameter	0	0.0025	0.0025	0.003	0.003
Over 0.3 " 1 " "	0.003	0	0.0025	0.0025	0.003	0.003
" 1 " 2 1/2 " "	0.004	0	0.004	0.004	0.004	0.004
" 2 1/2 in.	0.005	0	0.005	0.005	0.005	0.005

STANDARD METHODS OF TEST
FOR
MAGNETIC PROPERTIES OF IRON AND STEEL.

Serial Designation: A 34 – 18.

These methods are issued under the fixed designation A 34; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1911; Revised, 1912, 1914, 1918.

Core Loss.

The power consumption in electrical sheet steel when subjected to an alternating magnetization is known as the core loss. The standard core loss is the total power in watts consumed in each kilogram of material at a temperature of 25° C., when subjected to a harmonically varying induction having a maximum of 10,000 gausses and a frequency of 60 cycles per second, when measured as specified below. It is represented by the symbol $W_{10/60}$.

The aging coefficient is the percentage change in the standard core loss after continued heating at 100° C. for 600 hours.

The standard core loss shall be measured under the following conditions:

The magnetic circuit shall consist of 10 kg. (22 lb.) of the test material, cut with a sharp shear into strips 50 cm. ($19\frac{11}{16}$ in.) long and 3 cm. ($1\frac{3}{16}$ in.) wide, half parallel and half at right angles to the direction of rolling, made up into four equal bundles, two containing material parallel and two containing material at right angles to the direction of rolling, and finally built into the four sides of a square with butt joints and opposite sides consisting of material cut in the same manner. No insulation other than the natural scale of the material (except in the case of scale-free material) shall be used between laminations, but the corner joints shall be separated by tough paper 0.01 cm. (0.004 in.) thick.

The magnetizing winding shall consist of four solenoids surrounding the four sides of the magnetic circuit and joined in series. A secondary coil shall be used for energizing the voltmeter and the potential coil of the wattmeter.

These solenoids shall be wound on a form of any non-magnetic non-conducting material of the following dimensions:

Inside cross-section	4 by 4 cm.
Thickness of wall	not over 0.3 cm.
Winding length	42 cm.

The primary winding on each solenoid shall consist of 150 turns of copper wire uniformly wound over the 42-cm. length. The total resistance of the magnetizing winding shall be between 0.3 and 0.5 ohm. The secondary winding of 150 turns of copper wire on each solenoid shall be similarly wound beneath the primary winding. Its resistance shall not exceed 1 ohm.

A voltmeter and the voltage coil of a wattmeter shall be connected in parallel to the terminals of the secondary winding of the apparatus. The current coil of the wattmeter shall be connected in series with the primary winding.

A sine wave electromotive force shall be applied to the primary winding and adjusted until the voltage of the secondary circuit is given by the equation:

$$E = \frac{4 f N n B M}{4 l D 10^8}$$

in which

f = form factor of primary E.M.F. = 1.11 for sine wave
N = number of secondary turns = 600
n = number of cycles per second = 60
B = maximum induction = 10.000
M = total mass in grams = 10,000
l = length of strips in centimeters = 50
D = specific gravity = 7.5 for high-resistance steel
= 7.7 for low-resistance steel
E = 106.6 volts for high-resistance steel for sine voltage.
= 103.8 volts for low-resistance steel for sine voltage.

A specific gravity of 7.5 is assumed for all steels having a resistance of over 2 ohms per meter-gram, and 7.7 for all steels having a resistance of less than 2 ohms per meter-gram. These steels are designated as high and low-resistance steels, respectively.

The wattmeter gives the power consumed in the iron and the secondary circuit. The loss in the secondary circuit is given in terms of the total resistance and voltage. Subtracting this correction term from the total power gives the net power consumed in the steel as hysteresis and eddy-current loss. Dividing this value by ten gives the core loss in watts per kilogram.

Sampling.—The core-loss material shall be cut from two or more sheets taken at random from the shipment. The strips should be distributed symmetrically over the sheet, as nearly as may be practicable. For example, see Figs. 1 and 2.

It is recommended that a test sample shall represent not more than 5000 kg. (11,000 lb.).

The Procedure.—1. Cut the test material into strips 3 by 50 cm. as indicated under "Sampling."

2. Place on the balance a pile of strips weighing 2.5 kg. Add a second pile of the same kind, bringing the weight up to 5 kg. In each case the weight is taken to the nearest strip. Add in succession two piles of 2.5 kg. each, of the other kind of strips, bringing the weight up to 7.5 kg. and 10 kg. respectively.

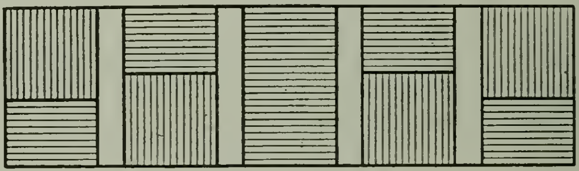

FIG. 1.

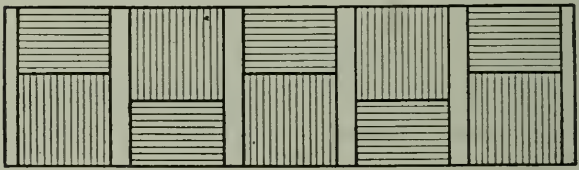

FIG. 2.

3. Secure each bundle by string or tape (not wire) and insert in the apparatus as indicated.

4. Apply the alternating voltage to the primary coil and tap the joints together until the current has a minimum value, as shown by an ammeter in series. Then clamp the corners firmly by some suitable device.

5. Shunt the ammeter and adjust the primary current until the voltmeter indicates the proper value. This adjustment may be made by an auto-transformer, by varying the field of the alternator, or by both, but not by the insertion of resistance or inductance in the primary circuit. Simultaneously the frequency must be adjusted to 60 cycles.

6. Read the wattmeter.

7. Calculations. Subtract from the wattmeter reading the instrument losses, which will be constant for any set of instruments and voltage, and divided by 10. The result is the standard core loss.

NORMAL INDUCTION.

The normal magnetic induction is the induction produced by a magnetizing force in a given piece of magnetic material which has been previously demagnetized and then subjected to many reversals of the given magnetizing force.

Both the induction B and the magnetizing force H shall be expressed in terms of the c. g. s. electromagnetic unit (gauss).

Sheet Metal.—The standard normal induction data for sheet material shall consist of the magnetizing forces corresponding to inductions of 2000, 4000, 6000, 8000, 10,000, 12,000, 14,000, 16,000, 18,000, 20,000 gausses, or such as may be obtained without exceeding a magnetizing force of 200 gausses.

The following details are to be observed:

The permeability sample for sheet material shall consist of an even number of strips cut parallel to the direction of rolling and an even number cut perpendicular to this direction, selected from material sampled as for core loss.

The sample shall weigh not less than 1 nor more than 2 kg.

The magnetic circuit shall be a rectangle having the test material for one pair of opposite sides, and the same or different material for the other pair, which may be shorter. The joints at each corner are alternately butt and lap, or may be clamped on the edges.

The magnetomotive force is applied in two sections. The main magnetizing coils shall consist of two equal and uniformly wound solenoids surrounding the test material. The compensating coils shall consist of four short coils, each having the same number of turns wound closely over the ends of the magnetizing coils.

A test coil surrounds the middle portion of each bundle of test material. Four other test coils each of half the number of turns are placed over the four positions of the test material, approximately midway between the yokes and the center. The two center test coils are joined in series and the four end test coils are joined in series. The corresponding ballistic deflections, due to these two sets of test coils, are measures of the magnetic fluxes through the underlying portions of the magnetic circuit. By connecting the two test coils so that the induced electromotive force opposes that of the four coils, and adjusting the current through the compensating magnetizing coils so that there is no resulting ballistic deflection, an approximate uniformity of flux is secured through the greater portion of the test material, and the induction may be measured ballistically in the regular manner. The magnetizing force when the flux is adjusted to uniformity is that calculated from the uniform winding of the main magnetizing solenoids.

The cross-section of the magnetic circuit is determined as in the standard core-loss test.

Rods.—The standard test for rods for use in electromagnets shall consist of the magnetizing forces corresponding to inductions of 2000, 4000, 6000, 8000, 10,000, 12,000, 14,000, 16,000, 18,000, 20,000 gausses, or such as may be obtained without exceeding a magnetizing force of 200 gausses.

RESIDUAL INDUCTION AND COERCIVE FORCE.

The magnetic induction which exists in a piece of magnetic material when the magnetizing force has been reduced to zero is called the residual induction. The magnetizing force required to reduce this induction to zero is called the coercive force. The values of the residual induction and the coercive force depend upon the previous magnetic history. If the magnetic material has been normalized by proper demagnetization and repeated reversals of the magnetizing force, the corresponding quantities are called the normal residual induction (B_r) and the normal coercive force (H_c).

The standard data for material intended for permanent magnets shall consist of the normal induction (B), the normal residual induction (B_r), and the normal coercive force (H_c) corresponding to a magnetizing force of 200 gausses.

The standard magnetic data shall be determined by the Burrows compensated double-yoke method on test specimens prepared as indicated below.

The permeameter opening shall have a rectangular cross-section of 2 by 5 cm. (0.79 by 1.97 in.)

Sampling.—Each mill heat or lot shall be marked separately. The test sample shall consist of one test specimen from each of six different bars.

Size of Test Specimen.—The test specimen shall be 25 cm. (9.84 in.) or more long and shall be of such cross-section that it will pass through a rectangular tube whose cross-section is 2 by 5 cm. (0.79 by 1.97 in.).

Heat Treatment.—For steels of the following approximate chemical composition:

Carbon	0.50 – 0.70	per cent
Manganese	0.50 – 1.00	"
Phosphorus	0.05	"
Sulfur	0.03	"
Silicon	0.10	"

heat the specimen to 825° C. (1517° F.) and quench in water at 20° C.

For tungsten steel, heat the specimen to 845° C. (1550° F.) and quench in water at 20° C.

For other alloy steels, the heat treatment is to be determined by practical tests on the test specimen.

The furnace shall be of such size that the specimen is heated to the required temperature in not over 30 minutes.

The furnace temperatures given above shall not vary by more than 10° C.

On quenching, the test specimen shall be removed quickly from the furnace. The test specimen shall not be allowed to cool over 10° C., after leaving the furnace and before immersion.

Immerse end-on or edgewise. The quantity of water shall be such that after quenching its temperature is not over 50° C.

STANDARD METHODS OF CHEMICAL ANALYSIS OF PLAIN CARBON STEEL.

Serial Designation: A 33 – 14.

These methods are issued under the fixed designation A 33; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1914.

DETERMINATION OF CARBON BY THE DIRECT-COMBUSTION METHOD.

The method of direct combustion of the metal in oxygen is recommended, the carbon dioxide obtained being absorbed in barium-hydroxide solution, the precipitated barium carbonate filtered off, washed, dissolved in a measured excess of hydrochloric acid and the excess titrated against standard alkali.

The use of potassium-hydroxide solution or soda lime for the absorption of carbon dioxide, with suitable purifying train following the furnace, is recognized as being capable of very satisfactory refinement and as possessing merit where the time element is of prime significance.

Owing to the diversity of apparatus by which correct results may be obtained in the determination of carbon, the recommendations are intended more to indicate what is acceptable than to prescribe definitely what shall be used.

Apparatus.

Purifying Train.—The method employed eliminates the necessity of a purifying train following the furnace, inasmuch as no precautions are necessary to prevent access of water vapor, or sulfur trioxide—the impurities usually guarded against—from the absorbing apparatus. All that is needed is a calcium-chloride tower filled with stick sodium hydroxide placed before the furnace, or between the furnace and catalyzer, if, as recommended, the latter is used for the purpose of oxidizing organic matter in the oxygen.

Material for Lining Boats.—Alundum, "RR Alundum, alkali-free, specially prepared for carbon determination," as supplied by dealers is suitable, and is recommended. The 90-mesh or finer grades are used. Chromite, properly sized and freed from materials causing a blank, may also be employed. No substance containing alkali or alkaline earth metals, or carbon as carbonates or in other form, should be used as a lining material. Quartz sand, owing to its liability to fuse or to slag with the oxides of iron, causing bubbles of gas to be enclosed, is objectionable. Aluminum oxide, made by calcining alum or otherwise, often contains sulfate not easily destroyed, or may contain objectionable substances of an alkaline nature.

Catalyzers.—Suitable catalyzers are copper oxide, platinized quartz or asbestos, or platinum gauze. One of these should be used in the forward part of the combustion apparatus, as well as in the purifying train preceding the combustion tube (see above). Platinized materials sometimes give off volatile substances on heating, and whatever material is used should not be subject to this defect.

Combustion Apparatus.—Any apparatus heated by gas or electricity which will bring the sample to a temperature of 950 to 1100° C. may be used. Combustion tubes may be porcelain, glazed on one or both sides, quartz or platinum. Quartz is liable to devitrification when used continuously at temperatures above 1000° C., and may then become porous. Combustion crucibles of platinum may be heated by blast or by Meker burners.

Boats or Other Containers of Samples being Burned.—These may be of porcelain, quartz, alundum, clay, platinum, or nickel, and should always receive a lining of granular alundum.

Purifying Train before Combustion Apparatus.—This consists of a tower filled with stick sodium hydroxide, preceded by a catalyzer.

The Train after the Combustion Apparatus.—This consists merely of the Meyer tube for absorption of the carbon dioxide, protected by a soda-lime tube at the far end. Meyer tubes with 7 to 10 bulbs of 10 to 15-cc. capacity each, and large bulbs at the ends, having volumes equal to the combined capacity of the small bulbs, have been used and found satisfactory.

Filtering Apparatus.—In filtration for accurate work, care should be taken to protect the solution from access of extraneous carbon dioxide. This is accomplished in the apparatus shown in Fig. 1. For work requiring less accuracy, the barium carbonate may be filtered off on a filter made by fitting a carbon funnel with a perforated porcelain disk and filtering by suction. The precipitate is then washed with distilled water from which the carbon dioxide has been removed by boiling.

REAGENTS.

Oxygen.—Oxygen of not less than 97-per-cent purity is recommended. Endeavor should be made to obtain oxygen which gives no blank, since the correction for or elimination of this is troublesome and uncertain. For the most accurate work, particularly with low-carbon products, such as ingot iron, etc., the blank should be completely eliminated by the use of a catalyzer before the furnace, with a carbon-dioxide absorbent interposed between furnace and catalyzer.

Tenth-normal Hydrochloric Acid.—This may be standardized by any of the accepted methods, or as follows: Twenty cubic centimeters of the approximately N/10 acid is measured out with a pipette, and the silver chloride precipitated by an excess of silver-nitrate solution in a volume of 50 to 60 cc. After digesting at 70 to 80° C., until the supernatant liquid is clear, the chloride is filtered off on a tared Gooch filter and washed with water containing 2 cc. of nitric acid per 100 cc. of water until freed from silver nitrate. After drying to constant weight at 130° C., the increase of weight over the original tare is noted and from this weight, corresponding to the silver chloride, the strength of the hydrochloric acid is calculated, after which it is adjusted to the strength prescribed. The standardization should be based upon several concordant determinations using varying amounts of acid.

$$1 \text{ cc. } N/10 \text{ HCl} = 0.0006 \text{ g. carbon.}$$

Methyl Orange.—Dissolve 0.02 g. in 100 cc. of hot distilled water and filter.

Tenth-normal Sodium-Hydroxide Solution.—This is standardized against the hydrochloric acid. Methyl orange is used as the indicator. The sodium-hydroxide solution should be stored in a large bottle from which it may be driven out by air pressure, protecting against carbon dioxide by soda-lime tubes.

Barium-Hydroxide Solution.—A saturated solution is filtered and stored in a large reservoir from which it is delivered by air pressure, protecting from carbon dioxide by a soda-lime tube.

Three or four small bulbs of the Meyer tube are filled, and CO_2-free water is added until the remaining small bulbs are filled.

FACTORS INFLUENCING RAPID COMBUSTION.

Size of Particles of Sample.—The finer the chips the better, except with samples which burn too vigorously (see under "Rate of Admitting Oxygen"). Particles too coarse to pass a 20-mesh sieve are not recommended, nor long curly drillings which will not pack closely. A ½-in. flat drill may be used for taking the sample and the pressure and speed of the drill-press regulated to secure the desired result; or, better still, the sample may be obtained with a small milling machine suitable for sampling, or by a shaping machine. Oil, dust, and other foreign matter should be carefully excluded.

Manner of Distributing Sample in Boat.—This is of considerable importance. With all samples, close packing in a small space is conducive to rapid combustion. In the case of samples which burn too vigorously, a satisfactory regulation may sometimes be attained by spreading the sample loosely over the lining in the boat.

Rate of Admitting Oxygen.—The rate at which oxygen is admitted is also a factor in the velocity of combustion. Assuming the combustion apparatus to be heated to the temperature range recommended above (950 to 1100° C.), it is possible, if the material is closely packed and if oxygen is admitted at too rapid a rate, that the combustion may be so violent as to cause excessive spattering of fused oxides, and such fluidity of the molten slag that the boat or other container may be injured or destroyed; therefore a moderate rate of burning is to be sought. This is desirable also from the standpoint of the complete absorption of the carbon dioxide by the barium-hydroxide solution. The factors, temperature of combustion apparatus, manner of distribution of sample, and rate of admission of oxygen, can be governed so as to burn successfully steels of a very wide range of compositions, in either fine or coarse particles.

METHOD.

After having properly set up and tested the apparatus, place 2 g. of steel (see note No. 1) in the form recommended above, in a moderately packed condition on the bed material and introduce the boat into the combustion apparatus, already heated to the proper temperature. After about a minute (to allow the sample and container to reach the temperature of the furnace), admit oxygen somewhat more rapidly than it is consumed, as shown by the rate of bubbling in the Meyer tube (see note No. 2). The sample burns completely in 1 or 2 minutes, and all that is now necessary is to sweep all the carbon dioxide into the absorption apparatus. This can be accomplished in 6 to 8 minutes by passing about 1 or 2 liters of oxygen. Detach the Meyer tube (see note No. 2) and filter and wash the barium carbonate, using the special filtering apparatus shown. After solution in a measured excess of hydrochloric acid (the Meyer tube being washed out with a portion of the acid, to remove adhering barium carbonate), titrate the excess of acid against alkali and from the data thus obtained calculate the percentage of carbon.

NOTES.

1. When working with steels high in carbon (above 1 per cent) it is advisable not to use more than 1 g. in order that filtration may be sufficiently rapid.

2. As a precaution against error resulting from too rapid passage of the gases, it is well to attach a second barium-hydroxide tube to retain any carbon dioxide that may pass the first.

3. For the most accurate work the Meyer tubes should be washed with dilute acid before beginning work each day. After a determination is finished the tube should be completely filled two or three times with tap water, then rinsed with distilled water, in order to remove the carbon dioxide liberated when dissolving the carbonate from the previous determination.

4. The flask containing the carbonate should be thoroughly agitated after adding the acid, since the carbonate sometimes dissolves rather slowly if this is not done; this is particularly the case if it has packed much during filtration.

APPARATUS AND PROCEDURE FOR FILTRATION.

The apparatus is shown to approximately one-tenth size in Fig. 1, which is self-explanatory. The stop-cock is a three-way cock connected to the suction pipe. The rubber tubing connected to the Meyer tube should be of best-grade black rubber, and the lengths used should be so chosen as to permit of easy manipulation of the tube. The Meyer tube is connected or disconnected by the rubber stoppers which are left always attached to the rubber tubes. The carbon tube *C* is fitted with a perforated porcelain plate sliding easily.

The funnel is prepared for filtration by making on the porcelain disk a felt of asbestos about $\frac{1}{16}$ to $\frac{1}{8}$ in. in thickness, using amphibole (not serpentine) asbestos which has been carefully digested with strong hydrochloric acid for several hours and washed with water until it gives no acid reaction. On top of the asbestos pad is placed a layer of similarly treated quartz, mixed with asbestos, of the height shown. A mixture of quartz grains of various sizes (approximately 50 per cent passing a 20-mesh sieve and 50 per cent passing a 10-mesh and remaining on a 20-mesh sieve) is suitable. The mixture of quartz and asbestos may be obtained by filling the funnel from a beaker (directing against it a stream from a wash-bottle) while maintaining a gentle suction. In this way the asbestos is properly mixed with the quartz. A little experience and attention to these details will enable one to prepare the quartz-bed in a manner that will greatly expedite filtration. The stopper is now inserted in the funnel, the Meyer tube connected as shown and the liquid and precipitate sucked into the funnel. Only a gentle suction should be used. When necessary P_3 is opened to admit air back of the column of liquid in the Meyer tube. When the contents of the Meyer tube have been transferred, the large bulb nearest *B* is half filled with water by opening P_1; the stop-cock *S* is operated during this and subsequent operations so as to maintain a gentle suction all the time. *M* is now manipulated so as to bring the wash water in contact with all parts of the interior, after which the water is sucked through *C*; P_2 is left open during this and subsequent washings. After

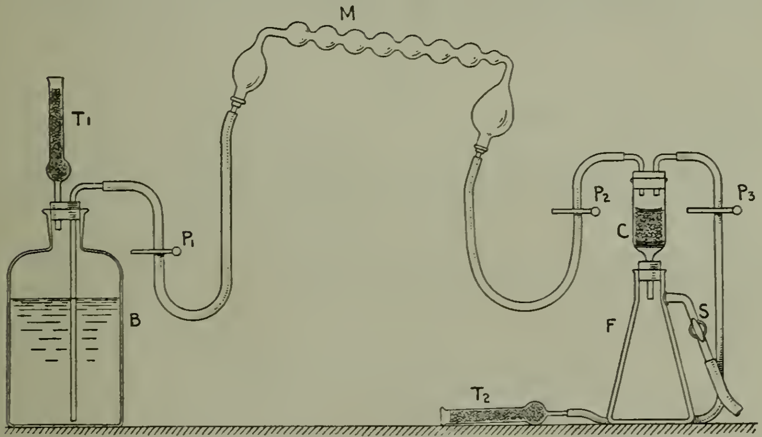

FIG. 1.—Apparatus for Filtration in Determination of Carbon by the Direct-Combustion Method.

eight washings as directed, allowing the wash water to drain off thoroughly each time before adding more, *M* may be detached, the stopper removed from the funnel and the washings completed by filling *C* to the top with CO_2-free water, sucking off completely and repeating the operation once. With care the washing may be done with 150 cc. of water. Air is now admitted through the side opening of *S*, *C* is removed and the porcelain disk carrying the asbestos, quartz and barium carbonate is thrust, by means of a long glass rod, into a flask removing any adhering particles from the sides of *C*, by a stream of water from a wash bottle. An excess of the standard acid is now added from a burette or pipette, using a portion to wash out *M*, and after the contents of the flask have been thoroughly agitated by shaking, the excess of acid is titrated against the standard alkali, using 3 drops of the methyl-orange indicator.

NOTES.

The operation of filtering can be carried out very rapidly after a little practice.

Glass wool should on no account be used as a substitute for the quartz, on account of the probability of errors arising from its attack by the alkali or acid.

It is well to wash out the rubber tubes connected to the Meyer tube with a little water each day before beginning work.

DETERMINATION OF CARBON
BY THE
COLORIMETRIC METHOD.
(ROUTINE.)

SOLUTION REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

METHOD.

In a small Erlenmeyer flask or test tube, dissolve 0.2 to 0.5 g. of steel, depending on the carbon content of the sample, in 5 to 20 cc. of the nitric acid. Boil gently until the solution is complete and the liquid is clear. Cool and compare with a solution of a standard steel treated under like conditions.

NOTE.

In order to obtain reliable results by this method the standard steel should be of the same kind, of approximately the same chemical composition, and in the same physical condition as the sample steel. The carbon content of the standard steel is determined by the direct combustion method.

DETERMINATION OF MANGANESE
BY THE
BISMUTHATE METHOD.

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 500 cc. of nitric acid, sp. gr. 1.42, and 1500 cc. of distilled water.

Nitric Acid for Washing.—Mix 30 cc. of nitric acid, sp. gr. 1.42, and 970 cc. of distilled water.

Stock Sodium Arsenite.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of sodium carbonate and 150 cc. of distilled water. Heat the flask and contents on a water bath until the arsenious oxide is dissolved, cool the solution and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite.—Dilute 300 cc. of stock-sodium-arsenite solution to 1000 cc. with distilled water and titrate against potassium-permanganate solution (about N/10), which has been standardized by using Bureau of Standards sodium oxalate.[1] Titrate 10-cc. portions of the permanganate solution, to each of which have been added 50-cc. portions of the nitric acid. A clear green color free from brownist or purplish tints will be found a satisfactory and reproducible end-point. Adjust the solution so that 1 cc. is equivalent to 0.10 per cent of manganese, on the basis of a 1-g. sample.

The factor $Na_2C_2O_4 \longrightarrow Mn = 0.16397$ (using the 1913 atomic weights).

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 1 g. of steel in 50 cc. of the nitric acid, and boil to expel the oxides of nitrogen. Cool, and add about $\frac{1}{2}$ g. of sodium bismuthate and heat for a few minutes, or until the pink color has disappeared, with or without precipitation of manganese dioxide. Add small portions of ferrous sulfate (or any suitable reducing agent) in sufficient quantity to clear the solution, and boil to expel the oxides of nitrogen. Cool to 15° C., add an excess of sodium bismuthate and agitate for a few minutes. Add 50 cc. of 3-per-cent nitric acid and filter through an alundum filter or asbestos pad, washing with 3-per-cent nitric acid. Titrate immediately with standard-sodium-arsenite solution to the disappearance of the pink color, each cubic centimeter required representing 0.10 per cent manganese.

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

NOTES.

In the method, the preliminary treatment with sodium bismuthate has been found by a number of investigators to be apparently unnecessary; however, the available data to confirm this position are not considered sufficient to warrant its omission.

In making the asbestos filter pad it is advisable to have a thin bed, and as much surface as possible. This insures rapid filtration, and the filter may be used until it becomes clogged with bismuthate.

The filtrate must be perfectly clear, since the least particle of bismuthate carried through the filter will vitiate the results.

DETERMINATION OF MANGANESE
BY THE
PERSULFATE METHOD.

(ROUTINE.)

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Silver Nitrate.—Dissolve 1.33 g. of silver nitrate in 1000 cc. of distilled water.

Stock Sodium Arsenite.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of sodium carbonate and 150 cc. of distilled water. Heat the flask and contents on a water bath until the arsenious oxide is dissolved, cool the solution and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite.—Dilute a sufficient quantity of stock-sodium-arsenite solution with distilled water, and standardize against a steel of known manganese content, as determined by the bismuthate method. This solution should be of such strength that each cubic centimeter will be equivalent to 0.10 per cent of manganese on the basis of the weight of sample taken.

METHOD.

In a small Erlenmeyer flask or large test tube, dissolve 0.1 to 0.3 g. of steel, depending on the manganese content of the sample, in 15 cc. of the nitric acid. Boil gently until the solution is complete and the liquid is clear. Add 15 cc. silver-nitrate solution and 1 g. of ammonium persulfate, and continue heating the solution for ½ minute after the oxidation begins and bubbles rise freely. Cool in running water and complete the determination by either of the following procedures:

(*a*) *Colorimetric.*—Compare the color of the solution with that of a standard steel treated under like conditions.

(*b*) *Titration.*—Titrate with standard-sodium-arsenite solution to the disappearance of the pink color, each cubic centimeter required representing 0.10 per cent of manganese.

NOTES.

In order to obtain reliable results by the colorimetric procedure, the standard should be of the same kind and of approximately the same chemical composition as the sample steel. The manganese content of the standard steel is determined by the bismuthate method.

The ammonium persulfate should be kept in moistened condition by small additions of distilled water at required intervals.

DETERMINATION OF PHOSPHORUS

BY THE

MOLYBDATE-MAGNESIA METHOD.

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. nitric acid, sp. gr. 1.42, and 1000 cc. of distilled water.

Potassium Permanganate.—Dissolve 25 g. of potassium permanganate in 1000 cc. of distilled water.

Ammonium Bisulfite.—Dissolve 30 g. of ammonium bisulfite in 1000 cc. of distilled water.

Ammonium Hydroxide, approximately 10-per-cent.—Mix 1000 cc. of ammonium hydroxide, sp. gr. 0.90, and 2000 cc. of distilled water.

Ammonium Molybdate.

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of ammonium hydroxide, sp. gr. 0.90, filter, and add 60 cc. of nitric acid, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of nitric acid, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

Magnesia Mixture.—Dissolve 50 g. of magnesium chloride and 125 g. of ammonium chloride in 750 cc. of distilled water, and then add 150 cc. of ammonium hydroxide, sp. gr. 0.90.

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 5 g. of steel in 75 cc. of the nitric acid. Heat to boiling; while boiling add about 12 cc. of the potassium-permanganate solution, and continue boiling until manganese dioxide precipitates. Dissolve this precipitate by additions of the ammonium-bisulfite solution, boil until clear and free from brown fumes, cool to 35° C., add 100 cc. of the ammonium-molybdate solution at room temperature, let stand 1 minute, shake or agitate for 3 minutes, filter on a 9-cm. paper and wash the precipitate at least 3 times with the 2-per-cent nitric-acid solution to free it from iron.

Treat the precipitate on the filter with the 10-per-cent ammonium-hydroxide solution, letting the solution run into a 100-cc. beaker containing 10 cc. of hydrochloric acid, sp. gr. 1.20, and 0.5 g. of citric acid; add 30 cc. of ammonium hydroxide, sp. gr. 0.90, cool, and then add 10 cc. of the magnesia mixture very slowly, while stirring the solution vigorously. Set aside in a cool place for 2 hours, filter and wash with the 10-per-cent ammonium-hydroxide solution. Ignite and weigh. Dissolve the precipitate of magnesium pyrophosphate with 5 cc. of nitric acid, sp. gr. 1.20, and 20 cc. of distilled water, filter and wash with hot water. Ignite and weigh. The difference in weights represents pure magnesium pyrophosphate containing 27.84 per cent of phosphorus.

NOTE.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

DETERMINATION OF PHOSPHORUS

BY THE

ALKALIMETRIC METHOD.

(ROUTINE.)

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of nitric acid, sp. gr. 1.42, and 1000 cc. of distilled water.

Potassium Permanganate.—Dissolve 25 g. of potassium permanganate in 1000 cc. of distilled water.

Ammonium Bisulfite.—Dissolve 30 g. of ammonium bisulfite in 1000 cc. of distilled water.

Ammonium Molybdate.

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of ammonium hydroxide, sp. gr. 0.90, filter and add 60 cc. of nitric acid, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of nitric acid, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water and let stand at least 24 hours before using.

Potassium Nitrate, 1-per-cent.—Dissolve 10 g. of potassium nitrate in 1000 cc. of distilled water.

Phenolphthalein Indicator.—Dissolve 0.2 g. in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium Hydroxide.—Dissolve 6.5 g. of purified sodium hydroxide in 1000 cc. of distilled water, add a slight excess of 1-per-cent solution of barium hydroxide, let stand for 24 hours, decant the liquid, and standardize it against a steel of known phosphorus content, as determined by the molybdate-magnesia method, so that 1 cc. will be equivalent to 0.01 per cent of phosphorus on the basis of a 2-g. sample (see notes). Protect the solution from carbon dioxide with a soda-lime tube.

Standard Nitric Acid.—Mix 10 cc. of nitric acid, sp. gr. 1.42, and 1000 cc. of distilled water. Titrate the solution against standardized sodium hydroxide, using phenolphthalein as indicator, and make it equivalent to the sodium hydroxide by adding distilled water.

Method.

In a 300-cc. Erlenmeyer flask dissolve 2 g. of steel in 50 cc. of the nitric acid. Heat the solution to boiling and while boiling add about 6 cc. of the potassium-permanganate solution and continue boiling until manganese dioxide precipitates. Dissolve this precipitate by additions of the ammonium-bisulfite solution, boil until clear and free from brown fumes, cool to 80° C., add 50 cc. of the ammonium-molybdate solution at room temperature, let stand 1 minute, shake or agitate for 3 minutes, and filter on a 9-cm. paper. Wash the precipitate three times with the 2-per-cent nitric-acid solution to free it from iron, and continue the washing with the 1-per-cent potassium-nitrate solution until the precipitate and flask are free from acid.

Transfer the paper and precipitate to a solution flask, add 20 cc. of distilled water, 5 drops of phenolphthalein solution as indicator, and an excess of standard-sodium-hydroxide solution. Insert a rubber stopper and shake vigorously until solution of the precipitate is complete. Wash off the stopper with distilled water and determine the excess of sodium-hydroxide solution by titrating with standard-nitric-acid solution. Each cubic centimeter of standard-sodium-hydroxide solution represents 0.01 per cent of phosphorus.

Notes.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

All distilled water used in titration should be freed from carbon dioxide by boiling or otherwise.

Bureau of Standards Standard Steel No. 19(*a*) is recommended as a suitable steel for standardization of the sodium-hydroxide solution.

DETERMINATION OF SULFUR
BY THE
OXIDATION METHOD.

Solution Required.

Barium Chloride.—Dissolve 100 g. of barium chloride in 1000 cc. of distilled water.

Method.

In a 400-cc. beaker dissolve 5 g. of the steel in a mixture of 40 cc. of nitric acid, sp. gr. 1.42, and 5 cc. of hydrochloric acid, sp. gr. 1.20, add 0.5 g. of sodium carbonate and evaporate the solution to dryness. Add 40 cc. of hydrochloric acid, sp. gr. 1.20, evaporate to dryness and bake at a moderate heat. After solution of the residue in 30 cc. of hydrochloric acid, sp. gr. 1.20, and evaporation to sirupy consistency, add 2 to 4 cc. of hydrochloric acid, sp. gr. 1.20, and then 30 to 40 cc. of hot water. Filter and wash with cold water, the final volume not exceeding 100 cc. To the cold filtrate add 10 cc. of the barium-chloride solution. Let stand at least 24 hours, filter on a 9-cm. paper, wash the precipitate first with a hot solution containing 10 cc. of hydrochloric acid, sp. gr. 1.20, and 1 g. barium chloride to the liter, until free from iron; and then with hot water till free from chloride. Ignite and weigh as barium sulfate.

Keep the washings separate from the main filtrate and evaporate them to recover any dissolved barium sulfate.

NOTE.

A blank determination on all reagents used should be made and the results corrected accordingly.

DETERMINATION OF SULFUR
BY THE
EVOLUTION-TITRATION METHOD.
(ROUTINE.)

APPARATUS.

Use a 480-cc. flask with a delivery tube and a 300-cc. tumbler of tall form (Fig. 2).

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid.—Mix 500 cc. of hydrochloric acid, sp. gr. 1.20, and 500 cc. of distilled water.

Ammoniacal Cadmium Chloride.—Dissolve 10 g. of cadmium chloride in 400 cc. of distilled water and add 600 cc. of ammonium hydroxide, sp. gr. 0.90.

Potassium Iodate.—Dissolve 1.116 g. of potassium iodate and 12 g. of potassium iodide in 1000 cc. of distilled water. Standardize with a steel of known sulfur content. Each cubic centimeter should be equivalent to 0.01 per cent of sulfur, when a 5-g. sample is used (see notes).

Starch.—To 1000 cc. of boiling distilled water, add a cold suspension of 6 g. of starch in 100 cc. of distilled water; cool, add a solution of 6 g. of zinc chloride in 50 cc. of distilled water, and mix thoroughly.

METHOD.

Place 5 g. of steel in the flask and connect the latter as shown in Fig. 2. Place 10 cc. of the ammoniacal-cadmium-chloride solution and 150 cc. of distilled water in the tumbler. Add 80 cc. of the dilute hydrochloric acid to the flask through the thistle tube, heat the flask with its contents gently until the solution of the steel is complete, then boil the solution for ½ minute. Remove the tumbler which contains all the sulfur as cadmium sulfide, and to it add 5 cc. of starch solution and 40 cc. of the dilute hydrochloric acid, titrating immediately with potassium-iodate solution to a permanent blue color.

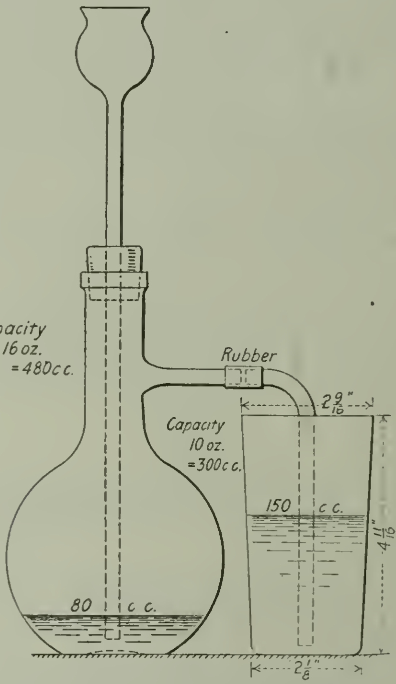

FIG. 2.—Apparatus for Determination of Sulfur by the Evolution Method.

NOTES.

Extremely slow or rapid evolution of hydrogen sulfide is to be avoided.

Bureau of Standards Standard Steel No. 8(*a*) is recommended for standardizing the potassium-iodate solution.

DETERMINATION OF SILICON
BY THE
NITRO-SULFURIC METHOD.

SOLUTIONS REQUIRED.

Nitro-Sulfuric Acid.—Mix 1000 cc. of sulfuric acid, sp. gr. 1.84, 1500 cc. of nitric acid, sp. gr. 1.42, and 5500 cc. of distilled water.

Dilute Hydrochloric Acid.—Mix 100 cc. of hydrochloric acid, sp. gr. 1.20, and 900 cc. of distilled water.

METHOD.

Add cautiously 80 cc. of the nitro-sulfuric acid to 4.702 g. of steel, in a platinum or porcelain dish of 300-cc. capacity, cover with a watch glass, heat until the steel is dissolved and evaporate slowly until copious fumes of sulfuric acid are evolved. Cool, add 125 cc. of distilled water, heat with frequent stirring until all salts are dissolved, add 5 cc. of hydrochloric acid, sp. gr. 1.20, heat for 2 minutes, and filter on a 9-cm. paper. Wash the precipitate several times with hot water, then with hot hydrochloric acid and hot water alternately to complete the removal of iron salts, and finally with hot water until free from acid. Transfer the filter to a platinum crucible, burn off the paper carefully with the crucible covered, finally igniting over a blast lamp or in a muffle furnace at 1000° C. for at least 20 minutes; cool in a desiccator and weigh. Add sufficient sulfuric acid, sp. gr. 1.84, to moisten the silica and then a small amount of hydrofluoric acid Evaporate to dryness, ignite and weigh. The difference in weights in milligrams divided by 100 equals the percentage of silicon.

NOTE.

A blank determination on all reagents used should be made and the results corrected accordingly.

DETERMINATION OF SILICON
BY THE
SULFURIC-ACID METHOD.
(OPTIONAL.)

SOLUTION REQUIRED.

Dilute Hydrochloric Acid.—Mix 100 cc. of hydrochloric acid, sp. gr. 1.20, and 900 cc. of distilled water.

METHOD.

To 2.351 g. of steel, in a beaker of low form of 500-cc. capacity, add 60 cc. of distilled water, and then cautiously 15 cc. of sulfuric acid, sp. gr. 1.84. Cover with a watch glass, heat until the steel is dissolved and evaporate until copious fumes of sulfuric acid are evolved. Cool, add 100 cc. of distilled water and heat with frequent stirring until the salts are in solution. Filter on a 9-cm. paper, wash the precipitate several times with cold water, then with cold dilute hydrochloric acid until free from iron, and finally with cold water until free from acid. Ignite and weigh. Add sufficient sulfuric acid, sp. gr. 1.84, to moisten the silica and then a small amount of hydrofluoric acid. Evaporate to dryness, ignite and weigh. The difference in weights in milligrams divided by 50 equals the percentage of silicon.

NOTE.

A blank determination on all reagents used should be made and the results corrected accordingly.

DETERMINATION OF COPPER

SOLUTIONS REQUIRED.

Sulfuric Acid.—Mix 200 cc. of sulfuric acid sp. gr. × 1.84, and 800 cc. of distilled water.

Potassium Ferrocyanide.—Dissolve 10 g. of potassium ferrocyanide in 100 cc. of distilled water.

Standard Copper Nitrate.—Dissolve 2 g. of purest electrolytic copper in 20 cc. of nitric acid (1: 1), and dilute to 1000 cc. with distilled water. Each cubic centimeter is equivalent to 0.02 per cent of copper on the basis of a 10-g. sample.

METHOD.

In a 300-cc. beaker dissolve 10 g. of the steel in 75 cc. of the sulfuric acid, and then add 150 cc. of distilled water. Heat the solution and saturate with hydrogen sulfide, filter and wash the precipitate free from iron with 1-per-cent sulfuric acid containing hydrogen sulfide. Incinerate the paper with its contents in a porcelain crucible and fuse with 0.5 g. of acid sodium sulfate. Extract with hot water, filter, and complete the determination colorimetrically as under 1 (*a*) or 1 (*b*), or electrolytically as under 2, as follows:

1. Evaporate the filtrate to about 25 cc., make faintly ammoniacal, filter into a 100-cc. Nessler tube and wash with hot water.

(*a*) If the solution is a strong blue, to another 100-cc. Nessler tube add 50 cc. of distilled water, 5 cc. of ammonium hydroxide, sp. gr. 0.90, and from a burette the standard-copper-nitrate solution until the blue colors match.

(*b*) If the solution is a faint blue, to the filtrate in a Nessler tube add the dilute sulfuric acid to faint acidity and then a few drops of the potassium-ferrocyanide solution. To another 100-cc. Nessler tube add 50-cc. of distilled water, a few drops of the potassium-ferrocyanide solution, and from a burette the standard-copper-nitrate solution until the reddish brown colors match.

2. Make the filtrate slightly acid with sulfuric acid, dilute with distilled water to a suitable volume, and determine the copper electrolytically.

DETERMINATION OF NICKEL
BY THE
GRAVIMETRIC DIMETHYLGLYOXIME METHOD.

SOLUTIONS REQUIRED.

Hydrochloric Acid.—Mix 500 cc. of hydrochloric acid, sp. gr. 1.20, and 500 cc. of distilled water.

Dimethylglyoxime.—Dissolve 1 g. of dimethylglyoxime in 100 cc. of 95-per-cent ethyl alcohol.

METHOD.

In a 150-cc. beaker dissolve 1 g. of the steel in 20 cc. of the hydrochloric acid, and add about 2 cc. of nitric acid, sp. gr. 1.42, to oxidize the iron. Filter the solution and add to the filtrate 6 g. of tartaric acid, and water till the volume is 300 cc. Make the solution faintly ammoniacal, then faintly acid with the hydrochloric acid and heat nearly to boiling; add 20 cc. of the dimethylglyoxime solution and then ammonium hydroxide, sp. gr. 0.90, drop by drop till faintly alkaline, stirring vigorously. After standing one hour, filter on a weighed Gooch crucible, wash with hot water, dry at 110 to 120° C. and weigh. The precipitate contains 20.31 per cent of nickel.

NOTES.

In making dimethylglyoxime solution, methyl alcohol may be substituted for ethyl alcohol.

The weight of sample taken should be varied according to the nickel content.

DETERMINATION OF NICKEL

BY THE

VOLUMETRIC DIMETHYLGLYOXIME METHOD.

(ROUTINE.)

SOLUTIONS REQUIRED.

Hydrochloric Acid.—Mix 500 cc. of hydrochloric acid, sp. gr. 1.20, and 500 cc. of distilled water.

Dimethylglyoxime.—Dissolve 1 g. of dimethylglyoxime in 100 cc. of 95-per-cent ethyl alcohol.

Silver Nitrate.—Dissolve 0.5 g. of silver nitrate in 1000 cc. of distilled water.

Potassium Iodide.—Dissolve 20 g. of potassium iodide in 100 cc. of distilled water.

Standard Potassium Cyanide.—Dissolve 2.29 g. of potassium cyanide in 1000 cc. of distilled water. Standardize this solution by the procedure described below, against a steel of known nickel content as determined by the gravimetric dimethylglyoxime method, so that each cubic centimeter is equivalent to 00.5 per cent of nickel on the basis of a 1-g. sample (see notes).

METHOD.

In a 150-cc. beaker dissolve 1 g. of the steel in 20 cc. of the hydrochloric acid, and add about 2 cc. of nitric acid, sp. gr. 1.42, to oxidize the iron. Filter the solution and add to the filtrate 6 g. of tartaric acid, and water until the volume is 300 cc. Make the solution faintly ammoniacal, then faintly acid with the hydrochloric acid, and cool thoroughly. Add 20 cc. of the dimethylglyoxime solution and then ammonium hydroxide, sp. gr. 0.90, drop by drop, till faintly alkaline, stirring vigorously. After standing for a few minutes, filter on a Gooch crucible and wash with hot water. Dissolve the precipitate on the filter with 10 to 20 cc. of nitric acid (hot), sp. gr. 1.42, added drop by drop, and then wash 5 times with hot water, using suction. To the solution in a 500-cc. beaker add 3 g. of ammonium persulfate and boil for 5 minutes. Cool, make distinctly ammoniacal, add 10 cc. each of the silver-nitrate and potassium-iodide solutions, and titrate with the standard-potassium-cyanide solution to a faint turbidity.

NOTES.

In making dimethylglyoxime solution, methyl alcohol may be substituted for ethyl alcohol.

Bureau of Standards Standard Steel No. 33 is recommended for standardizing the potassium-cyanide solution.

The weight of sample taken should be varied according to the nickel content.

DETERMINATION OF CHROMIUM.

SOLUTIONS REQUIRED.

Hydrochloric Acid.—Mix 500 cc. of hydrochloric acid, sp. gr. 1.20, and 500 cc. of distilled water.

Sodium Carbonate.—A saturated solution; approximately 60 g. of sodium carbonate and 100 cc. of distilled water.

Barium Carbonate.—Ten grams of finely divided barium carbonate suspended in 100 cc. of distilled water.

Standard Sodium Chromate.—Dissolve 2.6322 g. of sodium chromate in 1000 cc. of distilled water. Each cubic centimeter is equivalent to 0.02 per cent of chromium, when a 5-g. sample is used.

Standard Potassium Permanganate.—Dissolve 2 g. of potassium permanganate in 1000 cc. of distilled water. Standardize by using Bureau of Standards sodium oxalate,[1] and dilute the solution with distilled water so that 1 cc. is equivalent to 0.02 per cent chromium, when a 5-g. sample is taken.
The factor $Na_2C_2O_4 \longrightarrow Cr = 0.2584$ (using the 1913 atomic weights).

Ferrous Sulfate.—Dissolve 25 g. of ferrous ammonium sulfate in 900 cc. of distilled water and 100 cc. of sulfuric acid (1:1).

METHOD.

In a 300-cc. Erlenmeyer flask, covered, dissolve 5 g. of steel in 50 cc. of the hydrochloric acid. When completely dissolved, add gradually the saturated solution of sodium carbonate until practically all the free acid is neutralized; finish the neutralization with the barium-carbonate suspension, using an excess of about 1 g. of the carbonate. Boil the solution in the flask for 10 or 15 minutes, with the cover on. Filter the precipitate rapidly on paper and wash twice with hot water. Transfer the filter to a platinum crucible and after burning off the paper, fuse the residue for 10 minutes with a mixture of 5 g. of sodium carbonate and 0.25 g. of potassium nitrate. Dissolve the fusion in water, transfer to a beaker, add 2 cc. of 3-per-cent hydrogen peroxide, boil a few minutes and filter. Complete the determination of chromium in the filtrate by either of the following procedures:

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[1] *Circular No. 40*, Bureau of Standards. Oct. 1, 1912.

1. If the solution is a strong yellow, add 10 cc. of sulfuric acid (1 : 1), and then the ferrous-sulfate solution in measured excess. Cool thoroughly and titrate with the standard-potassium-permanganate solution. The number of cubic centimeters of the potassium-permanganate solution obtained, subtracted from the number corresponding to the volume of the ferrous-sulfate solution used, will give the volume of the potassium-permanganate solution equivalent to the chromium in the sample.

2. If the solution is a light yellow, cool the solution and transfer to a 100-cc. Nessler tube. To another Nessler tube add distilled water, and from a burette add the standard-sodium-chromate solution until the yellow colors match.

NOTE.

If procedure No. 1 is used, all hydrogen peroxide must be destroyed by boiling before acidifying, otherwise chromic acid will be reduced at this stage.

STANDARD METHODS OF CHEMICAL ANALYSIS OF ALLOY STEELS.

Serial Designation: A 55–15.

These methods are issued under the fixed designation A 55; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1915.

NICKEL STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[1]

DETERMINATION OF MANGANESE.

See the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[1]

See the Determination of Manganese in Plain Carbon Steel by the Persulfate Method (Routine).[1]

DETERMINATION OF PHOSPHORUS.

See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p 252

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten, or of copper or other metals precipitated by hydrogen sulfide from acid solutions.

The annealing of the steel drillings has been found by a number of investigators to increase the degree of refinement of the method.

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric-Acid Method (Optional).[1]

DETERMINATION OF NICKEL.

See the Determination of Nickel in Plain Carbon Steel by the Gravimetric Dimethylgloxime Method.[1]

See the Determination of Nickel in Plain Carbon Steel by the Volumetric Dimethylgloxime Method (Routine).[1]

DETERMINATION OF NICKEL
BY THE
ETHER EXTRACTION - CYANIDE TITRATION METHOD.

(OPTIONAL ROUTINE.)

SOLUTIONS REQUIRED.

Hydrochloric Acid.—Mix 600 cc. of hydrochloric acid, sp. gr. 1.20, and 400 cc. of distilled water.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Potassium Iodide.—Dissolve 20 g. of potassium iodide in 1000 cc. of distilled water.

Silver Nitrate.—Dissolve 0.5 g. of silver nitrate in 1000 cc. of distilled water.

Standard Potassium Cyanide.—Dissolve 4.589 g. of potassium cyanide in 1000 cc. of distilled water. Standardize the solution by the procedure described below, against a steel of known nickel content as determined by the gravimetric dimethylgloxime method, so that 1 cc. is equivalent to 0.10 per cent nickel on the basis of a 1-g. sample (see note).

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p. 252.

Method.

In a 150-cc. beaker dissolve 1 g. of the steel in 20 cc. of the hydrochloric acid, add about 2 cc. of nitric acid, sp. gr. 1.42, to oxidize the iron, and boil to expel the oxides of nitrogen. Cool, and transfer the solution into an 8-oz. separatory funnel, rinsing the beaker with small portions of the hydrochloric acid. Add 50 cc. of ether, shake for 5 minutes, let settle for 1 minute, and then draw off lower clear solution into another 8-oz. separatory funnel. Add 10 cc. of hydrochloric acid, sp. gr. 1.20, to the solution in the first separatory funnel, cool, shake thoroughly, allow to settle for 1 minute, and then draw off the lower clear solution into the second separatory funnel. To the combined solutions in the second separatory funnel add 50 cc. of ether, shake for 5 minutes, let settle for 1 minute, and then draw off the clear layer into a 150-cc. beaker. Heat the aqueous solution gently to expel the ether, add 0.2 g. of potassium chlorate, boil until chlorate is decomposed, dilute to 100 cc. with hot water, make faintly ammoniacal, and boil for 5 minutes. Filter and wash with hot water. To the filtrate add 10 cc. of hydrochloric acid, sp. gr. 1.20, heat just short of boiling and precipitate the copper with hydrogen sulfide. Filter and wash with hot water. Boil the filtrate to expel hydrogen sulfide, reducing the volume by evaporation to approximately 100 cc., cool, and make solution distinctly ammoniacal, add 10 cc. each of the silver-nitrate and potassium-iodide solutions, and titrate with the standard-potassium-cyanide solution to a clear solution.

Note.

Bureau of Standards Standard Steel No. 33, is recommended for standardizing the potassium-cyanide solution.

CHROME-NICKEL STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon by the Direct-Combustion Method.[1]

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p. 252.

DETERMINATION OF MANGANESE
BY THE
ZINC OXIDE-BISMUTHATE METHOD.

SOLUTIONS REQUIRED.

Sulfuric Acid.—Mix 200 cc. of sulfuric acid, sp. gr. 1.84, and 800 cc. of distilled water.

Nitric Acid.—Mix 500 cc. of nitric acid, sp. gr. 1.42, and 1500 cc. of distilled water.

Nitric Acid for Washing.—Mix 30 cc. of nitric acid, sp. gr. 1.42, and 970 cc. of distilled water.

Sodium Carbonate.—A saturated solution; approximately 60 g. of sodium carbonate and 100 cc. of distilled water.

Zinc Oxide.—Twenty grams of zinc oxide (dry process) suspended in 100 cc. of distilled water (see notes)

Stock Sodium Arsenite.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of sodium carbonate and 150 cc. of distilled water. Heat the flask and contents on a water bath until the arsenious oxide is dissolved, cool the solution and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite.—Dilute 300 cc. of the stock-sodium-arsenite solution to 1000 cc. with distilled water and titrate against potassium-permanganate solution (about N/10) which has been standardized by using Bureau of Standards sodium oxalate.[1] Titrate 10-cc. portions of the permanganate solution, to each of which have been added 50-cc. portions of the nitric acid. A clear green color free from brownish or purplish tints will be found a satisfactory and reproducible end-point. Adjust the solution so that 1 cc. is equivalent to 0.10 per cent of manganese on the basis of a 1-g. sample.

The factor $Na_2C_2O_4 \longrightarrow Mn = 0.16397$ (using the 1913 atomic weights).

METHOD.

In a platinum or porcelain dish of 300-cc. capacity, to 2.5 g. of the steel add 40 cc. of the sulfuric acid, cover with a watch glass, and heat until the steel is dissolved. Add about 4 cc. of nitric acid, sp. gr. 1.42, to oxidize the iron and evaporate slowly until copious fumes of sulfuric acid are evolved. Cool, add 100 cc. of hot water, heat with frequent stirring until all salts are dissolved, then transfer the solution into a volumetric

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912

500-cc. flask. Add the sodium-carbonate solution until near neutrality, and the precipitate formed dissolves with difficulty, then add small portions of the zinc-oxide suspension, shaking vigorously after each addition, until after settling of the coagulated precipitate, the supernatant liquid is practically clear. Cool, and make up to the mark with water. Mix thoroughly by pouring the entire contents of the flask into a large, dry beaker, and back again to the flask, repeating several times. Allow the precipitate to settle, filter off 200 cc. of the solution into a 300-cc. Erlenmeyer flask, add 75 cc. of the nitric-acid (sp. gr. 1.42), and boil to expel the oxides of nitrogen. Cool, add 0.5 g. of sodium bismuthate and heat for a few minutes, or until the pink color has disappeared, with or without the precipitation of manganese dioxide. Add small portions of ferrous sulfate (or other suitable reducing agent) in sufficient quantity to clear the solution, and boil to expel the oxides of nitrogen. Cool to 15° C., add an excess of sodium bismuthate and agitate for a few minutes. Let settle and filter through an alundum filter or asbestos pad, washing with the 3-per-cent nitric acid. Titrate immediately with the standard-sodium-arsenite solution to the disappearance of the pink color.

NOTES.

In the method, the preliminary treatment with sodium bismuthate has been found by a number of investigators to be apparently unnecessary; however the available data to confirm this position are not considered sufficient to warrant its omission.

In making the asbestos filter pad it is advisable to have a thin bed and as much surface as possible. This insures rapid filtration and the filter may be used until it becomes clogged with bismuthate.

The filtrate must be perfectly clear since the least particle of bismuthate carried through the filter will vitiate the results.

The zinc-oxide reagent should be free from manganese, or a correction applied if it is present.

DETERMINATION OF MANGANESE BY THE MODIFIED BISMUTHATE METHOD.

(ROUTINE.)

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 500 cc of nitric acid, sp. gr. 1.42, and 1500 cc. of distilled water.

Nitric Acid for Washing.—Mix 77 cc. of the nitric acid (.sp gr. 1.42.)

Stock Sodium Arsenite.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of sodium carbonate and 150 cc. of distilled water. Heat the flask and contents on a water bath until the arsenious oxide is dissolved, cool the solution and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite.—Dilute 300 cc. of the stock-sodium-arsenite solution to 1000 cc. with distilled water and titrate against potassium-permanganate solution (about N/10) which has been standardized by using Bureau of Standards sodium oxalate.[1] Titrate 10-cc. portions of the permanganate solution, to each of which have been added 50-cc. portions of the nitric acid. A clear green color free from brownish or purplish tints will be found a satisfactory and reproducible end-point. Adjust the solution so that 1 cc. is equivalent to 0.10 per cent of manganese on the basis of a 1-g. sample.

The factor $Na_2C_2O_4 \longrightarrow Mn = 0.16397$ (using the 1913 atomic weights).

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 1 g. of the steel in 50 cc. of the nitric acid, and boil to expel the oxides of nitrogen. Cool to 60–70° C., add about 0.5 g. of sodium bismuthate, and heat for a few minutes, or until the pink color has disappeared, with or without the precipitation of manganese dioxide. Add sufficient sulfurous acid or sodium sulfite to clear the solution and to reduce all of the chromic acid. Cool to approximately 0° C. in ice water, add an excess of sodum bismuthate and agitate. After 30 seconds standing, filter rapidly through an alundum filter or asbestos pad, washing with 3-per-cent nitric acid previously cooled in ice water to approximately 0° C. Titrate immediately with the standard-sodium-arsenite solution to the disappearance of the pink color.

NOTES.

In the method, the preliminary treatment with sodium bismuthate has been found by a number of investigators to be apparently unnecessary, however, the available data to confirm this position are not sufficient to warrant its omission.

In making the asbestos filter pad it is advisable to have a thin bed, and as much surface as possible. This insures rapid filtration, and the filter may be used until it becomes clogged with bismuthate.

The filtrate must be ice cold and perfectly clear, since any appreciable rise of temperature above 0° C., or the least particle of bismuthate carried through the filter will vitiate the results.

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

See the Determination of Manganese in Plain Carbon Steel by the Persulfate Method.[1]

NOTE.

In making the titration special care should be given to standardizing the end-point reading, and the reading should be corrected by a blank, which varies with the amount of chromium present.

DETERMINATION OF PHOSPHORUS.

See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method.[1]

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten, or of copper or other metals precipitated by hydrogen sulfide from acid solutions.

The annealing of the steel drillings has been found by a number of investigators to increase the degree of refinement of the method.

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric-Acid Method (Optional).[1]

DETERMINATION OF CHROMIUM
BY THE
FUSION METHOD.

SOLUTIONS REQUIRED.

Sulfuric Acid.—Mix 1000 cc. of sulfuric acid, sp. gr. 1.84, and 3000 cc. of distilled water.

Sodium Carbonate.—A saturated solution; approximately 60 g. of sodium carbonate and 100 cc. of distilled water.

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p. 252.

Magnesium Carbonate.—Ten grams of finely divided magnesium carbonate suspended in 100 cc. of distilled water.

Barium Carbonate.—Ten grams of finely divided barium carbonate suspended in 100 cc. of distilled water.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Potassium-Ferricyanide Indicator.—Dissolve 0.1 g. of potassium ferricyanide in 50 cc. of distilled water (see notes).

Standard Potassium Bichromate.—Dissolve 5 g. of potassium bichromate in 1000 cc. of distilled water, standardize against pure ferrous ammonium sulfate, and adjust to tenth-normal.

Ferrous Sulfate.—Dissolve 25 g. of ferrous ammonium sulfate in 900 cc. of distilled water and 100 cc. of sulfuric acid (1 : 1).

METHOD.

In a 300-cc. Erlenmeyer flask, covered, dissolve 1 g. of the steel in 50 cc. of the sulfuric acid (see notes). When completely dissolved, add 50 to 75 cc. of hot water, then gradually the sodium-carbonate solution until near neutrality, then add an excess of the magnesium-carbonate suspension (see notes), and boil vigorously for 15 minutes, with the cover on, adding fresh portions of the carbonate suspension during this time, so that there is present in the solution at the end of the operation an excess of 2 to 3 g. of the carbonate. Let settle and pour the supernatant liquid on a rapid filter, washing by decantation twice with cold water, pouring the washings through the filter. Transfer the filter to a platinum crucible and after burning off the paper, fuse the residue for 10 minutes with a mixture of 5 g. of sodium carbonate and 0.25 g. of potassium nitrate. Dissolve the fusion in water, transfer to a beaker, add 2 cc. of 3-per-cent hydrogen peroxide, boil a few minutes and filter. Add 20 cc. of the sulfuric acid, stir vigorously, cool and titrate against the standardized ferrous-sulfate solution, using the potassium-ferricyanide solution as outside indicator, or add at once a measured amount (in excess) of the ferrous-sulfate solution, and titrate back against the potassium-bichromate solution, using the same indicator.

NOTES.

The solution of the steel may be in hydrochloric acid, sp. gr. 1.20 or any other desired strength, adjusting the amount of acid used to avoid a large excess being present.

Barium-carbonate suspension may be substituted for the magnesium carbonate suspension when hydrochloric acid is used as solvent.

All hydrogen peroxide must be destroyed by boiling before acidifying, otherwise chromic acid will be reduced at this stage.

The insoluble residue remaining after extraction of the fusion should be examined for chromium.

The potassium-ferricyanide indicator should be prepared fresh on the day it is used.

The ferrous-sulfate solution should be standardized on the day it is used.

In titrating with the ferrous-sulfate solution it is convenient to divide the solution, roughly titrate one portion, add the other and finish carefully.

DETERMINATION OF CHROMIUM
BY THE
CHLORATE METHOD.
(ROUTINE.)

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Potassium-Ferricyanide Indicator.—Dissolve 0.1 g. of potassium ferricyanide in 50 cc. of distilled water (see notes).

Standard Potassium Bichromate.—Dissolve 5 g. of potassium bichromate in 1000 cc. of distilled water, and standardize against pure ferrous ammonium sulfate, and adjust to tenth-normal.

Standard Potassium Permanganate.—Dissolve 2 g. of potassium permanganate in 1000 cc. of distilled water. Standardize by using Bureau of Standards sodium oxalate.[1] Adjust the solution so that 1 cc. is equivalent to 0.10 per cent chromium on the basis of a 1-g. sample. The factor $Na_2C_2O_4 \longrightarrow Cr = 0.2584$ (using the 1913 atomic weights).

Ferrous Sulfate.—Dissolve 25 g. of ferrous ammonium sulfate in 900 cc. of distilled water and 100 cc. of sulfuric acid (1 :1).

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 1 g. of the steel in 30 cc. of the nitric acid, and evaporate rapidly to approximately one-half volume. Add 50 cc. of nitric acid, sp. gr. 1.42, and add 1 g. of sodium chlorate (see notes). Evaporate by boiling to approximately one-half volume and complete the determination by either of the following procedures:

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

1. Dilute the solution with 100 cc. of distilled water and filter off the manganese dioxide, using suction, washing with hot water. Cool the filtrate, dilute with cold water to 600-cc. volume, and titrate against the standard-ferrous-sulfate solution, using the potassium-ferricyanide solution as outside indicator, or add at once a measured amount (in excess) of the ferrous-sulfate solution and titrate back against the standard-potassium-bichromate solution, using the same indicator.

2. Add 10 cc. of hydrochloric acid (1:1) and boil until the solution is clear and all manganese dioxide dissolved. Cool, dilute the solution with water to 300-cc. volume, add the ferrous-sulfate solution in measured amount (in excess), and titrate back with the standard-potassium-permanganate solution to a permanent pink color.

NOTES.

The potassium-ferricyanide indicator should be prepared fresh on the day it is used.

The ferrous-sulfate solution should be compared on the day it is used, with the standard-potassium-permanganate or standard-potassium-bichromate solutions.

Potassium chlorate may be used as oxidizing agent in the place of sodium chlorate.

In titrating with the ferrous-sulfate solution it is convenient to divide the solution, roughly titrate one portion, add the other and finish carefully.

DETERMINATION OF CHROMIUM
BY THE
PERMANGANATE OXIDATION METHOD.

(OPTIONAL ROUTINE.)

SOLUTIONS REQUIRED.

Sulfuric Acid.—Mix 1000 cc. of sulfuric acid, sp. gr. 1.84, and 3000 cc. of distilled water.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Potassium Permanganate.—Dissolve 25 g. of potassium permanganate in 1000 cc. of distilled water.

Standard Potassium Permanganate.—Dissolve 2 g. of potassium permanganate in 1000 cc. of distilled water. Standardize by using Bureau of Standards sodium oxalate.[1] Adjust the solution so that 1 cc. is equivalent to 0.10 per cent chromium on the basis of a 1-g. sample.

The factor $Na_2C_2O_4 \longrightarrow Cr = 0.2584$ (using the 1913 atomic weights).

Ferrous Sulfate.—Dissolve 25 g. of ferrous ammonium sulfate in 900 cc. of distilled water and 100 cc. of sulfuric acid (1 : 1).

METHOD.

In a 300-cc. Erlenmeyer flask, dissolve 1.25 g. (procedure No. 1) or 1 g. (procedure No. 2) of the steel in 50 cc. of the sulfuric acid. When completely dissolved, add 5 cc. of the nitric acid, and boil until clear and free from oxides of nitrogen. Dilute with hot water to approximately 150-cc. volume, heat, and while boiling add the potassium-permanganate solution slowly until a permanent brown precipitate appears (see notes). Complete the determination by either of the following procedures:

1. Add 25 cc. of ammonium hydroxide, sp. gr. 0.90, shake well, place on the cooler part of the hot plate to avoid bumping. Shake occasionally and digest for about 15 minutes, or until the permanganate is all decomposed, then add cautiously 20 cc. of the sulfuric acid and bring gently to a boil. Cool the solution and pour into a volumetric 250-cc. flask. Make up to mark with cold water and mix thoroughly. Allow precipitate to settle, filter off 200 cc. of the clear solution (equal to 1 g.), add the ferrous-sulfate solution in measured amount (in excess) and titrate back with the standard-potassium-permanganate solution to a permanent pink color. The number of cubic centimeters of the standard-potassium-permanganate solution obtained, subtracted from the number corresponding to the volume of the ferrous-sulfate solution used, will give the volume of the standard-potassium-permanganate solution equivalent to the chromium in the sample.

2. Add 10 cc. of hydrochloric acid (1 : 1), and boil until the solution is clear and all manganese dioxide dissolved. Cool, dilute the solution with water to 300-cc. volume, add the ferrous-sulfate solution in measured amount (in excess), and titrate back with the standard-potassium-permanganate solution to a permanent pink color.

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

NOTES.

In oxidizing with the potassium-permanganate solution care should be taken to avoid a large excess, since the manganese-dioxide precipitate tends to hold the chromic acid.

In the solution of the manganese dioxide under procedure No. 2, the boiling should be continued until all chlorine fumes are expelled.

The ferrous-sulfate solution should be compared on the day it is used with the standard-potassium-permanganate solution.

DETERMINATION OF NICKEL.

See the Determination of Nickel in Plain Carbon Steel by the Gravimetric Dimethylglyoxime Method.[1]

See the Determination of Nickel in Plain Carbon Steel by the Volumetric Dimethylglyoxime Method (Routine).[1]

VANADIUM STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[1]

DETERMINATION OF MANGANESE.

See the Determination of Manganese in Chrome-Nickel Steel by the Zinc Oxide-Bismuthate Method.[2]

For the Routine Determination of Manganese, see the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[1]

DETERMINATION OF PHOSPHORUS
BY THE
MODIFIED MOLYBDATE-MAGNESIA METHOD.

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of nitric acid, sp. gr. 1.42, and 1000 cc. of distilled water.

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p. 252.

[2] Page 276.

Potassium Permanganate.—Dissolve 25 g. of potassium permanganate in 1000 cc. of distilled water.

Sodium Bisulfite.—Dissolve 30 g. of sodium bisulfite in 1000 cc. of distilled water.

Ammonium Molybdate.—Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of ammonium hydroxide, sp. gr. 0.90, filter, and add 60 cc. of nitric acid, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of nitric acid, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

Magnesia Mixture.—Dissolve 50 g. of magnesium chloride and 125 g. of ammonium chloride in 750 cc. of distilled water, and then add 150 cc. of ammonium hydroxide, sp. gr. 0.90.

Ammonium Hydroxide, Approximately 10-per-cent.—Mix 1000 cc. of ammonium hydroxide, sp. gr. 0.90, and 2000 cc. of distilled water.

Ferrous Sulfate.—A saturated solution; approximately 40 g. of ferrous sulfate and 100 cc. of distilled water.

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 5 g. of steel in 75 cc. of the nitric acid. Heat, and while boiling add about 12 cc. of the potassium-permanganate solution, and continue boiling until manganese dioxide precipitates. Dissolve the precipitate by additions of the sodium-bisulfite solution, boil until clear and free from oxides of nitrogen. Cool to 15–20° C., add 5 cc. of the ferrous-sulfate solution, and 2 or 3 drops of concentrated sulfurous acid, and then 100 cc. of the ammonium-molybdate solution. Let stand 1 minute, shake or agitate thoroughly for 5 minutes, filter on a 9-cm. paper and wash at least 3 times with the 2-per-cent nitric-acid solution to free from iron.

Treat the precipitate on the filter with the 10-per-cent ammonium-hydroxide solution, letting the solution run into a 100-cc. beaker containing 10 cc. of hydrochloric acid, sp. gr. 1.20, and 0.5 g. of citric acid; add 30 cc. of ammonium hydroxide, sp. gr. 0.90, cool, and then add 10 cc. of the magnesia mixture very slowly, while stirring the solution vigorously. Set aside in a cool place for 2 hours, filter and wash with the 10-per cent ammonium-hydroxide solution. Ignite and weigh. Dissolve, the precipitate of magnesium pyrophosphate with 5 cc. of nitric acid sp. gr. 1.20, and 20 cc. of water, filter and wash with hot water. Ignite and weigh. The difference in weights represents pure magnesium pyrophosphate containing 27.84 per cent of phosphorus.

NOTE.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

DETERMINATION OF PHOSPHORUS
BY THE
MODIFIED ALKALIMETRIC METHOD.

(ROUTINE.)

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of nitric acid, sp. gr. 1.42, and 1000 cc. of distilled water.

Potassium Permanganate.—Dissolve 25 g. of potassium permanganate in 1000 cc. of distilled water.

Sodium Bisulfite.—Dissolve 30 g. of sodium bisulfite in 1000 cc. of distilled water.

Ammonium Molybdate.—Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of ammonium hydroxide, sp. gr. 0.90, filter, and add 60 cc. of nitric acid, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of nitric acid, sp. gr. 14.2, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

Ferrous Sulfate.—A saturated solution; approximately 40 g. of ferrous sulfate and 100 cc. of distilled water.

Potassium Nitrate, 1-per-cent.—Dissolve 10 g. of potassium nitrate in 1000 cc. of distilled water.

Phenolphthalein Indicator.—Dissolve 0.2 g. of phenolphthalein in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium Hydroxide.—Dissolve 6.5 g. of purified sodium hydroxide in 1000 cc. of distilled water, add a slight excess of 1-per-cent solution of barium hydroxide, let stand for 24 hours, decant the liquid, and standardize it against a steel of known phosphorus content, as determined by the molybdate-magnesia method, so that 1 cc. will be equivalent to 0.01 per cent of phosphorus on the basis of a 2-g. sample (see notes). Protect the solution from carbon dioxide with a soda-lime tube.

Standard Nitric Acid.—Mix 10 cc. of nitric acid, sp. gr. 1.42, and 1000 cc. of distilled water. Titrate the solution against the standardized sodium hydroxide, using phenolphthalein as indicator, and make it equivalent to the sodium hydroxide by adding distilled water.

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 2 g. of steel in 50 cc. of the nitric acid. Heat, and while boiling add 6 cc. of the potassium-permanganate solution and continue boiling until manganese dioxide precipitates. Dissolve this precipitate by additions of the sodium-bisulfite solution, boil until clear and free from oxides of nitrogen, cool to 15–20° C., add 5 cc. of the ferrous-sulfate solution and 2 or 3 drops of concentrated sulfurous acid, and then 50 cc. of the ammonium-molybdate solution. Let stand for 1 minute, shake or agitate for 5 minutes, filter on a 9-cm. paper, wash the precipitate three times with the 2-per-cent nitric-acid solution to free it from iron, and continue the washing with the 1-per-cent potassium-nitrate solution until the precipitate and flask are free from acid.

Transfer the paper and precipitate to the solution flask, add 20 cc. of distilled water (see notes), 5 drops of phenolphthalein solution as indicator, and an excess of the standard-sodium-hydroxide solution. Insert a rubber stopper and shake vigorously until solution of the precipitate is complete. Wash off the stopper with distilled water and determine the excess of standard-sodium-hydroxide solution by titrating with standard-nitric-acid solution. Each cubic centimeter of standard-sodium-hydroxide solution represents 0.01 per cent of phosphorus.

NOTES.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

All distilled water used in titration should be freed from carbon dioxide by boiling or otherwise.

Bureau of Standards Standard Steel No. 24 is recommended as a suitable steel for standardizing the sodium-hydroxide solution.

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten, or of copper or other metals precipitated by hydrogen sulfide from acid solutions.

The annealing of the steel drillings has been found by a number of investigators to increase the degree of refinement of the method.

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric-Acid Method (Optional).[1]

DETERMINATION OF VANADIUM BY THE PHOSPHOMOLYBDATE - PRECIPITATION METHOD.

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of nitric acid, sp. gr 1.42, and 1000 cc. of distilled water.

Potassium Permanganate.—Dissolve 25 g. of potassium permanganate in 1000 cc. of distilled water.

Sodium Bisulfite.—Dissolve 30 g. of sodium bisulfite in 1000 cc. of distilled water.

Ammonium Phosphate.—Dissolve 50 g. of ammonium phosphate in 1000 cc. of distilled water.

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p. 252.

Ammonium Molybdate.—Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of ammonium hydroxide, sp. gr. 0.90, filter, and add 60 cc. of nitric acid, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of nitric acid, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

Acid Ammonium Sulfate.—Mix 50 cc. of sulfuric acid, sp. gr. 1.84, and 950 cc. of distilled water, and when cold add 15.cc. of ammonium hydroxide, sp. gr. 0.90. Use at a temperature of 80° C.

Standard Potassium Permanganate.—Dissolve 0.35 g. of potassium permanganate in 1000 cc. of distilled water, and standardize by using Bureau of Standards sodium oxalate.[1] Adjust the solution so that 1 cc. is equivalent to 0.02 per cent vanadium on the basis of a 2.5-g. sample.

The factor $Na_2C_2O_4 \longrightarrow V = 0.7612$ (using the 1913 atomic weights).

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 2.5 g. of steel in 50 cc. of the nitric acid. Heat, and while boiling add 6 cc. of the potassium-permanganate solution and continue boiling until manganese dioxide precipitates. Dissolve the precipitate by additions of the sodium-bisulfite solution and boil until clear and free from oxides of nitrogen. Add 5 cc. of the ammonium-phosphate solution and 10 g. of ammonium nitrate, heat to boiling, remove from the plate and add immediately 50 cc. of the ammonium-molybdate solution. Let stand 1 minute, shake or agitate for 3 minutes, filter the supernatant liquid by suction through an asbestos filter, and wash three times with the hot acid ammonium-sulfate solution. The flask containing the bulk of the precipitate is then set under the funnel fitted into a bell-jar filter and the asbestos pad is treated with successive small portions of hot sulfuric acid, sp. gr. 1.84. The solution is then heated until the precipitate is completely dissolved, a few drops of the nitric acid added, and the heating continued until copious fumes of sulfuric acid are evolved.

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

Cool the solution, add hydrogen peroxide in small quantities, with vigorous shaking after each addition, until the solution takes on a deep brown color. Replace flask on the hot plate, fume for 4 or 5 minutes, cover the flask, cool, add 100 cc. of distilled water, heat to 80° C. and titrate with the standard-potassium-permanganate solution to a permanent pink color.

NOTE.

If, after the addition of hydrogen peroxide and subsequent heating, the solution does not take on a clear green or blue color, it should be heated until fumes of sulfuric acid are evolved to rid of any traces of nitric acid which interferes with the reduction, then cooled and the treatment with hydrogen peroxide repeated.

DETERMINATION OF VANADIUM
BY THE
ETHER EXTRACTION - HYDROCHLORIC ACID REDUCTION METHOD.
(ROUTINE.)

SOLUTIONS REQUIRED.

Hydrochloric Acid.—Mix 600 cc. of hydrochloric acid, sp. gr. 1.20, and 400 cc. of distilled water.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Sulfuric Acid.—Mix 500 cc. of sulfuric acid, sp. gr. 1.84, and 500 cc. of distilled water.

Potassium Permanganate.—Dissolve 25 g. of potassium permanganate in 1000 cc. of distilled water.

Standard Potassium Permanganate.—Dissolve 0.35 g. of potassium permanganate in 1000 cc. of distilled water, and standardize by using Bureau of Standards sodium oxalate.[1] Adjust the solution so that 1 cc. is equivalent to 0.02 per cent vanadium on the basis of a 2.5 g. sample.

The factor $Na_2C_2O_4 \longrightarrow V = 0.7612$ (using the 1913 atomic weights).

METHOD.

In a 150-cc. beaker dissolve 2.5 g. of the steel in 50 cc. of the hydrochloric acid, add small portions of the nitric acid to oxidize the iron, and heat to expel the oxides of nitrogen. Cool, and transfer the solution into an 8-oz. separatory funnel, rinsing the beaker with small portions of the hydrochloric acid.

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

Add 50 cc. of ether, shake for 5 minutes, let settle for 1 minute, and then draw off lower clear solution into another 8-oz. separatory funnel. Add 10 cc. of hydrochloric acid, sp. gr. 1.20, to the solution in the first separatory funnel, shake thoroughly, allow to settle for 1 minute, and then draw off the lower clear solution into the second separatory funnel. To the combined solutions in the second separatory funnel add 50 cc. of ether, shake for 5 minutes, let settle for 1 minute, and then draw off the clear layer into a 150-cc. beaker. Heat the aqueous solution gently to expel the ether, add 25 cc. of the sulfuric acid, and heat until copious fumes are evolved. Cool, dilute with 25 cc. of water, add a slight excess of the potassium-permanganate solution, and boil. Add 15 cc. of hydrochloric acid, sp. gr. 1.20, and heat to fuming for 10 minutes. Cool, add 100 cc. of water, heat to 80° C., and titrate with the standard-potassium-permanganate solution to a permanent pink color.

NOTE.

In heating the solution to expel oxides of nitrogen care should be taken not to boil.

CHROME - VANADIUM STEEL.

DETERMINATION OF CARBON

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[1]

DETERMINATION OF MANGANESE.

See the Determination of Manganese in Chrome-Nickel Steel by the Zinc Oxide-Bismuthate Method.[2]

See the Determination of Manganese in Chrome-Nickel Steel by the Modified Bismuthate Method.[3]

DETERMINATION OF PHOSPHORUS.

See the Determination of Phosphorus in Vanadium Steel by the Modified Molybdate-Magnesia Method.[4]

See the Determination of Phosphorus in Vanadium Steel by the Modified Alkalimetric Method (Routine).[5]

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p. 252.

[2] Page 276.

[3] Page 277.

[4] Page 284.

[5] Page 286.

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten, or of copper or other metals precipitated by hydrogen sulfide from acid solutions.

The annealing of the steel drillings has been found by a number of investigators to increase the degree of refinement of the method.

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric-Acid Method (Optional).[1]

DETERMINATION OF CHROMIUM
BY THE
FUSION METHOD.

SOLUTIONS REQUIRED.

Sulfuric Acid.—Mix 1000 cc. of sulfuric acid, sp. gr. 1.84, and 3000 cc. of distilled water.

Sodium Carbonate.—A saturated solution; approximately 60 g. of sodium carbonate and 100 cc. of distilled water.

Magnesium Carbonate.—Ten grams of finely divided magnesium carbonate suspended in 100 cc. of distilled water.

Barium Carbonate.—Ten grams of finely divided barium carbonate suspended in 100 cc. of distilled water.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Potassium-Ferricyanide Indicator.—Dissolve 0.1 g. of potassium ferricyanide in 50 cc. of distilled water (see notes).

Standard Potassium Bichromate.—Dissolve 5 g. of potassium bichromate in 1000 cc. of distilled water, standardize against pure ferrous ammonium sulfate, and adjust to tenth-normal.

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33). p. 252.

Ferrous Sulfate.—Dissolve 25 g. of ferrous ammonium sulfate in 900 cc. of distilled water and 100 cc. of sulfuric acid (1 : 1). The strength of this solution should be expressed in terms of chromium and vanadium.

METHOD.

In a 300-cc. Erlenmeyer flask, covered, dissolve 1 g. of the steel in 50 cc. of the sulfuric acid (see notes). When completely dissolved, add 50 to 75 cc. of hot water, then gradually the sodium-carbonate solution until near neutrality, and then add an excess of the magnesium-carbonate suspension (see notes), and boil vigorously for 15 minutes, with the cover on, adding fresh portions of the carbonate suspension during this time, so that there is present in the solution at the end of the operation an excess of 2 to 3 g. of the carbonate. Let settle and pour the supernatant liquid on a rapid filter, washing by decantation twice with cold water, pouring the washings through the filter. Transfer the filter to a platinum crucible and after burning off the paper, fuse the residue for 10 minutes with a mixture of 5 g. of sodium carbonate and 0.25 g. of potassium nitrate. Dissolve the fusion in water, transfer to a beaker, add 2 cc. of 3-per-cent hydrogen peroxide, boil a few minutes and filter. Add 20 cc. of the sulfuric acid, stir vigorously, cool and titrate against the standardized ferrous-sulfate solution, using the potassium ferricyanide as outside indicator, or add at once a measured amount (in excess) of the ferrous-sulfate solution and titrate back against the standard-potassium-bichromate solution, using the same indicator.

From the number of cubic centimeters of the standard-ferrous-sulfate solution required deduct the number of cubic centimeters of the standard-ferrous-sulfate solution equivalent to the vanadium in the steel, as determined by the Phosphomolybdate-Precipitation Method for Vanadium Steel,[1] and the result will be the number of cubic centimeters of the standard-ferrous-sulfate solution equivalent to the chromium in the steel.

NOTES.

The solution of the steel may be in hydrochloric acid, sp. gr. 1.20 or any other desired strength, adjusting the amount of acid used to avoid a large excess being present.

Barium-carbonate suspension may be substituted for the magnesium-carbonate suspension when hydrochloric acid is used as solvent.

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[1] Page 288

All hydrogen peroxide must be destroyed by boiling before acidifying, otherwise chromic acid will be reduced at this stage.

The insoluble residue remaining after extraction of the fusion should be examined for chromium.

The potassium-ferricyanide indicator should be prepared fresh on the day it is used.

The ferrous-sulfate solution should be standardized on the day it is used.

In titrating with the ferrous-sulfate solution it is convenient to divide the solution, roughly titrate one portion, add the other and finish carefully.

DETERMINATION OF CHROMIUM
BY THE
CHLORATE METHOD.
(ROUTINE.)

SOLUTIONS REQUIRED.

Nitric Acid.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Potassium Ferricyanide Indicator.—Dissolve 0.1 g. of potassium ferricyanide in 50 cc. of distilled water (see notes).

Standard Potassium Bichromate.—Dissolve 5 g. of potassium bichromate in 1000 cc. of distilled water, standardize against pure ferrous ammonium sulfate, and adjust to tenth-normal.

Standard Potassium Permanganate.—Dissolve 0.5 g. of potassium permanganate in 1000 cc. of distilled water. Standardize by using Bureau of Standards sodium oxalate.[1] Adjust the solution so that 1 cc. is equivalent to 0.05 per cent vanadium on the basis of a 1-g. sample.

The factor $Na_2C_2O_4 \longrightarrow V = 0.7612$ (using the 1913 atomic weights).

Ferrous Sulfate.—Dissolve 25 g. of ferrous ammonium sulfate in 900 cc. of distilled water and 100 cc. of sulfuric acid (1 : 1). The strength of this solution should be expressed in terms of chromium and vanadium.

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 1 g. of the steel in 30 cc. of the nitric acid, and evaporate rapidly to approximately one-half volume. Add 50 cc. of nitric acid, sp. gr. 1.42, and 1 g. of sodium chlorate (see notes). Evaporate by boiling to one-half volume, dilute with 100 cc. of water and filter off the manganese dioxide, using suction, washing with hot water. Cool the solution to room temperature and complete the determination by either of the following procedures:

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

1. Titrate against the ferrous-sulfate solution, using the potassium-ferricyanide solution as outside indicator (see notes). From the number of cubic centimeters of the ferrous-sulfate solution required deduct the number of cubic centimeters of the ferrous-sulfate solution equivalent to the vanadium in the steel, as determined by the Phosphomolybdate-Precipitation Method for Vanadium Steel,[1] and the result will be the number of cubic centimeters of the ferrous-sulfate solution equivalent to the chromium in the steel.

2. Titrate against the ferrous-sulfate solution, using the potassium-ferricyanide solution as outside indicator (see notes). Cool to 15° C. and titrate against the standard-potassium-permanganate solution to a pink color permanent for 10 seconds. Deduct the number of cubic centimeters of the standard-potassium-permanganate solution consumed, which gives a direct measure of the vanadium content of the steel, from the first titration; the remainder will represent the chromium content of the steel.

NOTES.

The potassium-ferricyanide indicator should be prepared fresh on the day it is used.

The ferrous-sulfate solution should be compared on the day it is used with the standard-potassium-permanganate or potassium-bichromate solutions.

Potassium chlorate may be used as ozidizing agent in the place of sodium chlorate.

In titrating with the ferrous-sulfate solution it is convenient to divide the solution, roughly titrate one portion. add the other and finish carefully.

DETERMINATION OF VANADIUM.

See the Determination of Vanadium in Vanadium Steel by the Phosphomolybdate-Precipitation Method.[1]

DETERMINATION OF VANADIUM BY THE ETHER EXTRACTION - HYDROCHLORIC - ACID REDUCTION METHOD.

(ROUTINE.)

SOLUTIONS REQUIRED.

Hydrochloric Acid.—Mix 500 cc. of hydrochloric acid, sp. gr. 1.20, and 500 cc. of distilled water.

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[1] Page 288.

Standard Potassium Permanganate.—Dissolve 2 g. of potassium permanganate in 1000 cc. of distilled water, and standardize by using Bureau of Standards sodium oxalate.[1] Adjust the solution so that 1 cc. is equivalent to 0.10 per cent vanadium on the basis of when a 5-g. sample.

The factor $Na_2C_2O_4 \longrightarrow V = 0.7612$ (using the 1913 atomic weights).

METHOD.

In a 150-cc. beaker, dissolve 5 g. of the steel in 60 cc. of the hydrochloric acid, add small portions of nitric acid, sp. gr. 1.42, to oxidize the iron, avoiding an excess, and heat to expel the oxides of nitrogen. Cool, and transfer the solution into an 8-oz. separatory funnel, rinsing the beaker with small portions of the hydrochloric acid. Add 50 cc. of ether, shake for 5 minutes, let settle for 1 minute, and then draw off lower clear solution into another separatory funnel. Add 10 cc. of hydrochloric acid, sp. gr. 1.20, to the solution in the first separatory funnel, shake thoroughly, allow to settle for 1 minute, and then draw off the lower clear solution into the second separatory funnel. To the combined solution in the second separatory funnel add 50 cc. of ether, shake for 5 minutes, let settle for 1 minute, and then draw off the clear layer into a 150-cc. beaker. Heat the aqueous solution gently to expel the ether, evaporate to approximately one-fourth original volume, add 0.5 g. of potassium chlorate and boil down to a volume of 10 cc. Add 25 cc. of hydrochloric acid, sp. gr. 1.20, and again evaporate to 10 cc. Add 20 cc. of sulfuric acid, sp. gr. 1.84, and evaporate until copious fumes of sulfuric acid are evolved. Cool, dilute with water to 100-cc. volume, and titrate against the standard potassium permanganate to a pink color permanent for 10 seconds. Deduct the chromium blank and the remainder is equivalent to the vanadium content of the steel.

NOTE.

If much chromium relative to the vanadium is present the result will be high due to the oxidation of a portion of the chromium by the permanganate, and should be corrected by a blank which varies with the amount of the chromium present. This blank is conveniently made by putting a suitable amount of a chrome or chrome-nickel steel, free from vanadium, through the above process. By using varying amounts of this steel, so as to vary the chromium correspondingly, a curve may be constructed showing the relation between amount of chromium present and the amount of blank, and this curve can then be used in all subsequent work.

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

SILICO - MANGANESE STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[1]

DETERMINATION OF MANGANESE.

See the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[1]

See the Determination of Manganese in Plain Carbon Steel by the Persulfate Method (Routine).[1]

DETERMINATION OF PHOSPHORUS.

See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten, or of copper or other metals precipitated by hydrogen sulfide from acid solutions.

The annealing of the steel drillings has been found by a number of investigators to increase the degree of refinement of the method.

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric-Acid Method (Optional).[1]

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33), p. 252.

RECOMMENDED PRACTICE
FOR
ANNEALING OF MISCELLANEOUS ROLLED AND FORGED CARBON-STEEL OBJECTS.

Serial Designation: A 35-21.

This recommended practice is issued under the fixed designation A 35; the final number indicates the year of original adoption, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1921.

1. *Purpose and General Procedure.*—The usual purpose in annealing miscellaneous forged or rolled carbon-steel objects is to remove existing coarseness of grain. This removal is brought about by heating the object to an annealing temperature, which varies with the carbon content of the metal. But the rate at which the object cools from this annealing temperature influences its properties very profoundly. Hence this rate of cooling should be suited to the duties which the object has to perform in service, and hence to the properties which we seek to give it.

Therefore these specifications first consider the annealing temperature to which the piece must be heated in order to remove existing coarse grain, and then the rate of cooling from that temperature.

Under certain special conditions an annealing is required in order to remove, not coarseness of grain, but the effects of rolling or otherwise working the metal at a temperature so low as to set up serious internal stress. Appropriate treatment for these conditions is given in Section 14.

As these specifications are intended to apply to a great variety of miscellaneous objects, they are purposely made suggestive rather than mandatory in many respects, because no single set of rules can be applied rigorously to such widely varying classes of objects and purposes.

ANNEALING FOR REMOVING EXISTING COARSE GRAIN.

2. *Method of Heating.*—In the case of large objects, the heating of the interior of which lags behind that of the outside,

though the early part of the heating may if desired be rapid, the final approach to the annealing temperature aimed at should be slow, so that the interior may be brought fully up to it without carrying the exterior far beyond it, because in general any needlessly high temperature is injurious, and tends to re-coarsen the grain. The temperature should be held long enough at the annealing point to insure that the whole of the interior reaches that point, and that the refining of the grain may become complete. An exposure of 45 minutes should be long enough for each inch of thickness.

3. *Control of Temperature. Pyrometers.*—For all important work in careful hands the use of some trustworthy pyrometer is strongly recommended. But most pyrometers should be checked frequently against some standard. For those who are unwilling to take this trouble it is safer to rely on a trained eye than on an unchecked pyrometer. The operator should have clearly before him the fact that no pyrometer indicates the temperature of the interior of the object heated, and that the temperature which most pyrometers indicate is one between the temperature of the outside of the object heated and the temperature of the flame which is supplying the heat. Wherever practicable the part of the pyrometer which is supposed to reach the temperature of the object heated should be in immediate contact with that object, and should be protected from the flame or other source of heat by a suitable insulation, as for instance by covering it with sand. In important cases the gas or other source of heat should be shut off for at least ten minutes before taking the observation.

4. *Control Without the Use of a Pyrometer.*—In working without a pyrometer and relying on the eye, the light surrounding the furnace should be dull, and should be kept as nearly constant as practicable, in order that the eye may not be misled by the changing contrasts between the surrounding light and that of the object heated. In particular, direct sunlight should be excluded, and any arc or other strong lights should be so placed that neither they themselves nor any concentrated part of their light is in the field of the operator's sight when he is estimating by eye the temperature of the objects to be annealed. Allowance should be made for the brighter surroundings by day than at night, and on sunny than on dark days.

5. *Magnetic Indications.*—The annealing temperature for steels containing between 0.50 and 0.90 per cent of carbon is that at which the metal suddenly ceases to be magnetic. This

fact may sometimes be used for the purpose of fixing or verifying the annealing temperature.

6. *Annealing Temperature.*—In general, the higher the carbon content the lower should be the annealing temperature. Hence different temperatures are given for different ranges of carbon content. Further, in order to bring the interior of large objects up to an effective annealing temperature, their outside may often be raised advantageously somewhat above that temperature. Hence for each range of carbon content a range of temperature is given. The upper limit of this range applied (1) to larger objects, and (2) to the lower part of the range of carbon content given.

The following ranges of temperature should be used for the several ranges of carbon content indicated. They refer to the usual moderate manganese content. For steels with a manganese content greater than 0.75 per cent slightly lower temperatures suffice.

RANGE OF CARBON CONTENT.	RANGE OF ANNEALING TEMPERATURE.
Less than 0.12 per cent	875 to 925° C. (1607–1697° F.)
0.12 to 0.29 "	840 " 870 " (1544–1598 ")
0.30 " 0.49 "	815 " 840 " (1499–1544 ")
0.50 " 1.00 "	790 " 815 " (1454–1499 ")

7. *Care in Heating.*—Care should be taken that all parts of the object reach the same temperature. To that end it may be necessary to mask from the heat, by means of bricks, the thinner part of objects of varying thickness. When the heating is nearly finished, these bricks may be removed. In particular the flame should never be allowed to touch any part of the object under treatment.

8. *Cooling.*—After the object has been held at the annealing temperature long enough to make its temperature nearly uniform throughout, and to complete the refining of the grain, it should be cooled in a way suited to its carbon content and to giving it the specific properties needed. The general principles are: first, the higher the carbon the slower should be the cooling; and second, the slower the cooling the softer and more ductile the metal will be, and the lower will be its tensile strength, elastic limit, and yield point. The greatest softness and ductility are obtained at a certain sacrifice of strength and elasticity, and the greatest strength and elasticity at a certain sacrifice of softness and ductility.

For most purposes neither of these extremes is desired, and it is not only sufficient as regards quality but economical to remove the object from the furnace as soon as it has been thoroughly annealed, and to allow it to cool in air, always completely protected not only from rain and snow but from sharp drafts of air. Objects containing more than 0.50 per cent of carbon should cool more slowly till the color dies out, say at 500° C. (932° F.), as for instance by leaving them in the furnace. They may then be removed and cooled in air. Further, thin objects containing between 0.25 and 0.50 per cent of carbon should be treated like those of 0.50 per cent of carbon, unless they can be so massed together that their collective bulk will retard their cooling, so that they will collectively cool even in air with moderate slowness, like single large objects.

SPECIAL ANNEALING METHODS.

9. The foregoing methods are economical because they release the furnaces early for further use. In case special qualities are desired the following methods may be used:

10. *To Give the Greatest Softness and Ductility* of which the metal is capable, even at a certain sacrifice of strength and elastic limit, for instance for ease of machining or to resist a small number of severe distortions, the metal should be cooled slowly, either within the furnace, or in the case of large objects, under a cover of lime, clay, or other slow conductor of heat. The slower the cooling and the lower the temperature to which slow cooling is carried, the softer and weaker will be the steel. But for most cases for which even unusual softness and ductility are required, it suffices to remove the object from the furnace when it has become dead black, and to cool it thenceforth in air.

11. *To Give Great Tensile Strength and High Elastic Limit* even at a certain sacrifice of ductility, the cooling should be more rapid, the rapidity to be governed by the thickness and carbon content of the object. Thin objects and those with high carbon content cannot stand so rapid a cooling as thick and low-carbon ones, lest their ductility be too far sacrificed. For instance, thick objects with less than 0.50 per cent of carbon may be cooled completely in air, of course protected from rain or snow. Objects with 0.50 per cent of carbon or more, and thin objects with from 0.30 to 0.50 per cent of carbon, may be cooled in air if their cooling is somewhat retarded, as for instance by massing them together, as happens in the case of rails.

12. *To Give an Unusually High Combination of Ductility with Tensile Strength and Elastic Limit. Water or Oil Quenching and Annealing.*—This process needs great care and intelligence,

and should in general be used only by those familiar with high-grade steels. After holding at the annealing temperature suited to the particular steel, as indicated in Section 6, the object is quenched in oil, which should be kept in circulation. It may be quenched in water if its carbon content is so low and its shape so simple that it is not in danger of cracking or receiving permanently harmful stress. In any event the danger of such cracking and stress is lessened by removing the object from the oil or water before it has cooled completely, say when its temperature has fallen to 160° C. (320° F.). It should if possible not cool below 100° C. (212° F.) and certainly not below 20° C. (68° F.). The annealing should begin within a very few hours after the quenching and if possible without ever allowing the piece to cool below 100° C. (212° F.) and certainly not below 20° C. (68° F.).

The steel thus hardened should next be annealed by heating to a temperature suited for giving the properties needed. In general the higher this annealing goes, the more ductile will the steel become, and the lower will be its strength and elastic limit.

For very high elastic limit and tensile strength, anneal at 500 to 650° C. (932 to 1202° F.). In this case the ductility will be low. Some steels, such as watch-springs and shafting, are annealed at 350° C. Little commercial annealing is done below 500° C.

For intermediate tensile strength, elastic limit, and ductility, best suited to the majority of cases, anneal at 600 to 650° C. (1112 to 1202° F.).

For the greatest ductility, with good strength and elastic limit, anneal at from 725 to 750° C. (1337 to 1382° F.).

The object should be held at this second annealing temperature long enough not only to allow its interior to reach it, but also to relieve the stress given in the water or oil quenching. For pieces of moderate thickness a 4-hour exposure should suffice.

13. *To Give a Moderate Increase of Strength and Elastic Limit above that Given by a Simple Slow Cooling, without the Full Sacrifice of Ductility which a Simple Air Cooling would Cause.*—After holding at the annealing temperature suited to the carbon content, as indicated in Section 6, hasten the cooling till the object is at a dull red, say 650° C. (1202° F.), and henceforth cool slowly. The hastening of the cooling may be brought about in the case of thin objects in relatively shallow furnaces by opening the furnace door till the temperature falls to dull redness; or by running the objects out into the air on a movable car-

bottom, and returning them to the furnace when they have cooled to dull redness. In cases in which such operations are to be performed frequently, special unfired chambers may be used for the final slow cooling, thus leaving the annealing furnaces proper available for their regular work. The results obtained in this way are not as good as those obtained with the method described in Section 11.

14. *Special Annealing to Remove the Effects of Rolling or Otherwise Working the Object in the Cold or at any Unduly Low Temperature.*—The object should be heated to about 775° C. (1427° F.) and cooled with a slowness which should increase with the thickness, that is, the least dimension of the piece. In the case of thin plates a mere heating to 725° C. (1337° F.), followed immediately by slow cooling, should suffice. In the case of thick forgings, in which much time may be needed to allow severe stress to relieve itself, the sojourn at 775° C. (1427° F.) may be prolonged for several hours, though always at the cost of superficial decarburizing.

Such annealing for steel containing less than 0.15 per cent carbon should be at 900° C. (1652° F.). Great brittleness may be caused by annealing very low carbon steel in the neighborhood of 700° C. (1292° F.), after cold working.

RECOMMENDED PRACTICE
FOR
ANNEALING OF CARBON-STEEL CASTINGS.

Serial Designation: A 36 – 14.

This recommended practice is issued under the fixed designation A 36; the final number indicates the year of original adoption, or in the case of revision, the year of last revision.

ADOPTED, 1914.

1. The castings should preferably be sufficiently cleaned of adhering sand before annealing to ensure thorough and uniform heating.

2. The castings should be heated slowly and uniformly to temperatures varying with the carbon content of the steel, approximately as follows:

CARBON, PER CENT.	TEMPERATURE, DEG. CENT.
Up to 0.16	925
0.16 to 0.34	875
0.35 to 0.54	850
0.55 to 0.79	830

Nothing in these recommendations shall operate against the temperatures aimed at being 50 and, in special cases, 100° C. higher than those given in the table, when necessary to attain the desired result.

3. The castings should be kept at the maximum temperature a sufficient length of time to ensure the refining of the grain. In general, the heavier the sections of the casting, the longer must be the time of exposure to the maximum temperature.

4. (*a*) The castings should be cooled slowly and uniformly in the furnace, when it is desired that the steel shall possess the maximum softness.

(*b*) The castings may be cooled at an accelerated rate, when it is desired that the steel possess rather higher tensile strength and elastic limit than can be procured by very slow cooling. This cooling must be so conducted as to leave the steel reasonably free from cooling stresses.

The manner of carrying out this accelerated cooling should be such as will attain the desired result. For instance, the castings may be withdrawn from the furnace and buried in a bed of material that is a poor conductor of heat; or the annealing furnace may be so thrown open that it will cool more rapidly than if left closed. Should the castings be of such uneven section that they cool at unequal rates at various points when the furnace is opened, especially if the carbon of the steel is high, the furnace should be closed after the castings have become black, and their further cooling so retarded that the stresses set up by the unequal rates of cooling are relieved.

RECOMMENDED PRACTICE

FOR

HEAT TREATMENT OF CASE-HARDENED CARBON-STEEL OBJECTS.

Serial Designation: A 37 – 14.

This recommended practice is issued under the fixed designation A 37; the final number indicates the year of original adoption, or in the case of revision, the year of last revision.

Adopted, 1914.

It is recommended that the following treatments be applied to case-hardened carbon-steel objects according to requirements:

1. When hardness of case only is desired and lack of toughness or even brittleness unimportant, the carburized objects may be quenched from the carburizing temperature, as for instance, by emptying the contents of the boxes in cold water or in oil. Both the core and the case are then coarsely crystallin.

2. In order to reduce the hardening stresses and to decrease the danger of distortion and cracking in the quenching bath, the objects may be removed from the box and allowed to cool before quenching to a temperature slightly exceeding the critical range of the case, namely, 800 to 825° C. Both the core and case remain coarsely crystallin.

3. To refine the case and increase its toughness, the carburized objects should be allowed to cool slowly in the carburizing box within the furnace or outside to 650° C. or below, and should then be reheated to a temperature slightly exceeding the lower critical point of the case (in the majority of instances a temperature varying in accordance with the carbon content and thickness of the case between 775 and 825° C. will be suitable), and quenched in water, or, for greater toughness but less hardness, in oil. The objects should be removed from the quenching bath before their temperature has fallen below 100° C. This treatment is more especially to be recommended when the carburizing temperature has not exceeded 900° C. It refines the case but not the core.

4. To refine both the core and the case and to increase their toughness, the objects should be allowed to cool slowly from the carburizing temperature to 650° C. or below and should then be (*a*) reheated to a temperature exceeding the critical point of the core, which will generally be from 900 to 950° C., followed by quenching in water or in oil; and (*b*) before they have cooled below 100° C.,[1] they should be reheated to a temperature slightly exceeding the lower critical point of the case (in the majority of instances a temperature varying in accordance with the carbon content and thickness of the case between 775 and 825° C. will be suitable), and again quenched in water or oil.

5. In order to reduce the hardening stresses created by quenching, the objects, as a final treatment, may be tempered by reheating them to a temperature not exceeding 200° C.

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[1] The objects should be removed from the quenching bath before they have cooled below 100° C. in order to lessen the danger of cracking, and they should be placed in the reheating furnace while still at a temperature of at least 100° C. likewise to lessen the danger of cracking, it being inadvisable (*a*) to allow steel to cool completely in the quenching bath and (*b*) to place hardened steel in a hot furnace. Obviously, if the furnace is cold the hardened steel may likewise be cold when placed in it for reheating.

STANDARD SPECIFICATIONS
FOR
LAP-WELDED CHARCOAL-IRON BOILER TUBES FOR LOCOMOTIVES.

Serial Designation: A 38-21.

These specifications are issued under the fixed designation A 38; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1912; Revised, 1916, 1918, 1921.

Material Covered. 1. These specifications cover lap-welded charcoal-iron boiler tubes, boiler flues, safe ends, and arch tubes for locomotives.

I. MANUFACTURE.

Process. 2. The tubes shall be made from knobbled, hammered charcoal iron.

II. PHYSICAL PROPERTIES AND TESTS.

Bend Tests. 3. (*a*) *Quench-bend Tests.*—Strips ½ in. in width by 6 in. in length, planed lengthwise from tubes, when heated to a cherry red and quenched at once in water the temperature of which is 80° F., shall bend in opposite directions at each end, as shown in Fig. 1, without showing cracks or flaws.

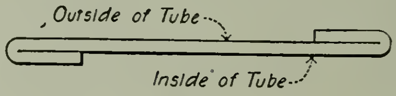

Fig. 1.

(*b*) *Nick-bend Tests.*—Strips ½ in. in width by 6 in. in length, planed lengthwise from tubes, when nicked and broken by light blows, shall show a wholly fibrous fracture.

Expansion Tests. 4. A test specimen 12 in. in length shall be heated for a length of 5 in. to a bright cherry red (1200–1400° F.), placed in a vertical position, and a smooth tapered steel pin at blue heat (600–800° F.) forced into the end of the tube by pressure or by light blows of a 10-lb. hammer. Under this test the tube shall expand to 1⅛ times its original diameter without splitting or cracking. The pin shall be of tool steel and shall have a taper of $1\frac{1}{2}$ in. per foot of length.

Crush Tests. 5. A test specimen $2\frac{1}{2}$ in. in length shall withstand crushing longitudinally without splitting, cracking or opening at the weld as follows: Tubes 10 B.w.g. or lighter to a height of $1\frac{1}{8}$ in., if heavier than 10 B.w.g. to a height of $1\frac{3}{4}$ in.

Hydrostatic Tests. 6. Tubes under 5 in. in diameter shall stand an internal hydrostatic pressure of 1000 lb. per sq. in., and tubes 5 in. or over in diameter shall stand an internal hydrostatic pressure of 800 lb. per sq. in.; provided that the fiber stress does not exceed 16,000 lb. per sq. in., in which case the test pressure shall be determined by the following formula:

$$P = \frac{32{,}000\ t}{D}$$

in which P = the pressure in pounds per square inch, t = the thickness of wall in inches, and D = the inside diameter of tube in inches. Lap-welded tubes shall be struck near both ends, while under the test pressure, with a 2-lb. steel hand hammer or the equivalent.

Etch Tests.[1] 7. In case of doubt as to the quality of material, the following test shall be made to detect the presence of steel. A cross-section of tube shall be turned or ground to a perfectly true surface, polished free from dirt or cracks, and etched until the soft parts are sufficiently dissolved for the iron tube to show a decided ridged surface, with the weld very distinct, while a steel tube would show a homogeneous surface.

Test Specimens 8. (*a*) Test specimens shall consist of sections cut from tubes selected by the inspector representing the purchaser from the lot offered for shipment. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests 9. One of each of the physical tests specified shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

Retests. 10. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified in Sections 3, 4, or 5, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

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[1] A solution of two parts water, one part HCl (sp. gr. 1.20) and one part H_2SO_4 (sp. gr. 1.84) is recommended for the etch test.

III. STANDARD WEIGHTS.

Standard Weights.

11. The standard weights for tubes of various outside diameters and thicknesses, are as indicated in Table I.

12. (*a*) The weight of tubes under 3½ in. in outside diameter shall vary not more than 5 per cent above or below that specified in Table I.

(*b*) Tubes 3½ in. and over in outside diameter may vary 2½ per cent below and 7½ per cent above that specified.

IV. WORKMANSHIP AND FINISH.

Workmanship.

13. (*a*) Finished tubes 3½ in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 3½ in. in outside diameter these variations shall not exceed 0.5 per cent of the outside diameter.

TABLE I.—STANDARD WEIGHTS FOR LAP-WELDED CHARCOAL-IRON BOILER TUBES FOR LOCOMOTIVES.

INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

Thickness.		Weight, lb. per Foot of Length, Outside Diameter, in.													
B.w.g.	In.	1¾	1⅞	2	2¼	2½	3	3½	4	4½	5	5¼	5⅜	5½	6
13	0.095	1.679	1.806	1.932	2.186	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	1.910	2.055	2.201	2.492	2.783	3.365	.....	.....	.....	.....	.....	.....	.....	.....
11	0.120	2.089	2.249	2.409	2.729	3.050	3.691	4.331	.....	.....	.....	.....	.....	.....	.....
10	0.134	2.312	2.491	2 670	3 028	3.386	4.101	4.817	5.532	.....	.....	.....	.....	.....	.....
9	0.148	2.532	2.729	2.927	3.322	3.717	4.508	5.298	6.088	6.879	7.669	8.064	8.262	8 459	9.250
8	0.165	.....	.....	.....	.....	4.114	4.995	5.877	6.758	7.639	8.520	8.960	9.181	9 401	10 282
7	0.180	.....	.....	.....	.....	4.460	5.421	6.382	7.343	8.301	9.266	9.746	9.987	10.227	11.188

(*b*) The thickness at any point shall not vary more than 2 gages above or one gage below that specified. In the case of boiler tubes which are expanded and swaged, the thickness of the expanded end may be 1½ gages lighter and of the swaged end 2 gages heavier than the thickness specified.

(*c*) The length shall not be less, but may be 0.125 in. more than that ordered.

Finish.

14. The finished tubes shall be free from injurious defects and distortion, and shall have a workmanlike finish.

V. MARKING.

Marking.

15. The name or brand of the manufacturer, the words "knobbled charcoal," and the pressure in pounds at which it was tested, shall be legibly stenciled on each tube.

VI. INSPECTION AND REJECTION.

16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tubes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

17. Tubes when inserted in the boiler shall stand expanding and beading without splitting or breaking. Tubes which fail in this manner will be rejected, and the manufacturer shall be notified. **Rejection.**

STANDARD SPECIFICATIONS
FOR
WELDED WROUGHT-IRON PIPE.

Serial Designation: A 72 – 21.

These specifications are issued under the fixed designation A 72; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted, 1918; Revised, 1921.

Material Covered. 1. These specifications cover "standard" and "extra strong" welded wrought-iron pipe, but not "double extra strong" pipe.

Basis of Purchase. 2. All pipes to be used on locomotives and cars shall be of coiling or bending quality.

I. MANUFACTURE.

Process. 3. (*a*) The iron shall be made from muck bars, made from puddled pig iron, free from any admixture of iron scrap or steel.

(*b*) All pipe 3 in. or under in nominal diameter may be butt-welded, unless otherwise specified. All pipe over 3 in. in nominal diameter shall be lap-welded.

Definition of Scrap. 4. *Iron Scrap.*—This terms applies only to foreign or bought scrap and does not include local mill products, free from foreign or bought scrap.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 5. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	40 000
Yield point, lb. per sq. in.	24 000
Elongation in 8 in., per cent	12

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Hydrostatic Tests. 6. All pipe shall be tested at the mill to the hydrostatic pressures specified in Table I.

TABLE I.—HYDROSTATIC PRESSURES FOR WELDED WROUGHT-IRON PIPE.

(Pressures Expressed in Pounds per Square Inch)

(BLACK AND GALVANIZED)

Size, (Nominal Inside Diameter), in.	"Standard" Pipe.			"Extra Strong" Pipe.		
	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Butt-Weld.	Lap-Weld.	Weight of Pipe per Linear Foot, Plain Ends, lb.	Butt-Weld.	Lap-Weld.
$\frac{1}{8}$	.....	700	....	.....	700	....
$\frac{1}{4}$	.....	700	....	.....	700	....
$\frac{3}{8}$	.....	700	....	.....	700	....
$\frac{1}{2}$	.....	700	....	.....	700	....
$\frac{3}{4}$	.....	700	....	.....	700	....
1	.....	700	....	.....	700	....
$1\frac{1}{4}$	.....	700	1000	.....	1500	2500
$1\frac{1}{2}$	.....	700	1000	.....	1500	2500
2	.....	700	1000	.....	1500	2500
$2\frac{1}{2}$	.....	800	1000	.....	1500	2000
3	.....	800	1000	.....	1500	2000
$3\frac{1}{2}$	.....	...	1000	.....	....	2000
4	.....	...	1000	.....	....	2000
$4\frac{1}{2}$	.....	...	1000	.....	....	1800
5	.....	...	1000	.....	....	1800
6	.....	...	1000	.....	....	1800
7	.....	...	1000	.....	....	1500
8	25.00	...	800	.....	....	....
8	28.81	...	1000	43.39	....	1500
9	34.19	...	900	48.73	....	1200
10	32.00	...	600	.....	....	....
10	35.00	...	700	.....	....	....
10	41.13	...	900	54.74	....	1000
11	46.25	...	800	60.08	....	1000
12	45.00	...	600	.....	....	....
12	50.71	...	800	65.42	....	1000

For pipes over 12 in. in insidediameter, the test pressures should be calculated by the formula $P = \frac{2St}{D}$ in which P = pressure in pounds per square inch; S = fiber stress = 12,000 lb. per sq. in.; t = thickness of wall in inches; D = inside diameter in inches.

TABLE II.—STANDARD WEIGHTS OF WELDED WROUGHT-IRON PIPE.

(BLACK AND GALVANIZED)

Size (Nominal Inside Diameter), in.	"Standard" Pipe.				"Extra Strong" Pipe.	
	Outside Diameter, in.	Number of Threads per Inch.	Thickness, in.	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.
1/8	0.405	27	0.068	0.25	0.095	0.31
1/4	0.540	18	0.088	0.43	0.119	0.54
3/8	0.675	18	0.091	0.57	0.126	0.74
1/2	0.840	14	0.109	0.85	0.147	1.09
3/4	1.050	14	0.113	1.13	0.154	1.47
1	1.315	11 1/2	0.133	1.68	0.179	2.17
1 1/4	1.660	11 1/2	0.140	2.28	0.191	3.00
1 1/2	1.900	11 1/2	0.145	2.73	0.200	3.63
2	2.375	11 1/2	0.154	3.68	0.218	5.02
2 1/2	2.875	8	0.203	5.82	0.276	7.66
3	3.500	8	0.216	7.62	0.300	10.25
3 1/2	4.000	8	0.226	9.20	0.318	12.51
4	4.500	8	0.237	10.89	0.337	14.98
4 1/2	5.000	8	0.247	12.64	0.355	17.61
5	5.563	8	0.258	14.81	0.375	20.78
6	6.625	8	0.280	19.19	0.432	28.57
7	7.625	8	0.301	23.77	0.500	38.05
*8	8.625	8	0.277	25.00	.....	.....
8	8.625	8	0.322	28.81	0.500	43.39
9	9.625	8	0.342	34.19	0.600	48.73
*10	10.750	8	0.279	32.00	.....	.....
*10	10.750	8	0.307	35.00	.....	.....
10	10.750	8	0.365	41.13	0.500	54.74
11	11.750	8	0.375	46.25	0.500	60.08
*12	12.750	8	0.330	45.00	.....	.....
12	12.750	8	0.375	50.71	0.500	65.42

* Unless specifically stated on the order the lighter weights will not be furnished. Weights given in the tables are for pipes up to and including 12 in. in nominal inside diameter, with threaded ends and couplings; sizes larger than shown in the table are measured by the outside diameter and will be furnished with plain ends; for such sizes it will be necessary to accept Manufacturers' weights or calculcate the weights on the basis of one cubic inch of iron weighing 0.2833 lb.

Fracture Tests. 7. A section of pipe 6 in. in length shall be flattened until broken by repeated light blows of a hammer or by pressure; the fracture developed shall have a fibrous appearance.

Bend Tests. 8. For pipe 2 in. or under in diameter, a sufficient length of coiling or bending pipe shall withstand being bent cold through 90 deg., around a cylindrical mandrel the diameter of which is 15 times the nominal diameter of the pipe, without developing cracks at any portion and without opening the weld.

Test Specimens. 9. (*a*) Test specimens shall consist of sections cut from a pipe. They shall be smooth on the ends and free from burrs.

(*b*) Tension test specimens shall be longitudinal.

(*c*) All specimens shall be tested cold.

Number of Tests. 10. One of each of the tests specified in Sections 5, 7 and 8, may be made on a length in each lot of 500 or less, of each size. Each length shall be subjected to the hydrostatic test.

Retests. 11. If the results of the physical tests of any lot do not conform to the requirements specified in Sections 5, 7 and 8, retests of two additional pipes shall be made, each of which shall conform to the requirements specified.

III. STANDARD WEIGHTS.

Standard Weights. 12. (*a*) The standard weights for pipe of various inside diameters are given in Table II.

(*b*) Nipples shall be cut from pipe of the same weight and quality as described in these specifications.

Permissible Variations. 13. The weight of the pipe shall not vary more than 5 per cent from that specified in Table II.

Lengths. 14. Unless otherwise specified, pipe shall be furnished as to lengths in accordance with the following regular practice:

(*a*) Standard pipe shall be in random lengths from 16 to 22 ft., but not more than 5 per cent of the total number of lengths may be "jointers," which are two pieces coupled together. When ordered with plain ends, 5 per cent may be in lengths of 12 to 16 ft.

(*b*) Extra strong pipe shall be in random lengths of 12 to 22 ft. and 5 per cent may be in lengths of 6 to 12 ft.

IV. WORKMANSHIP AND FINISH.

Workmanship. 15. (*a*) For pipe $1\frac{1}{2}$ in. or under in inside diameter, the outside diameter at any point shall vary not more than $\frac{1}{64}$ in. over nor more than $\frac{1}{32}$ in. under the standard size. For pipe 2 in. or over in inside diameter, the outside diameter shall vary not more than 1 per cent over or under the standard size.

16. Unless otherwise specified, pipe shall conform to the following regular practices:

Ends. (*a*) Each end of standard pipe shall be threaded.

(*b*) Extra strong pipe shall be furnished with plain ends.

Threads. (*c*) All threads shall be in accordance with the American Standard[1] and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed a maximum of one and one-half turns either way.

Couplings. (*d*) Each length of threaded pipe shall be provided with one coupling, having clean-cut threads of such a pitch diameter as to make a tight joint. Couplings shall be of wrought iron.

Finish. 17. The finished pipe shall be reasonably straight and free from injurious defects. All burrs at the ends of the pipe shall be removed.

V. INSPECTION AND REJECTION.

Inspection. 18. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, free of charge, all reasonable facilities to satisfy him that the pipe are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 19. Each length of pipe which develops injurious defects in shop working or application will be rejected, and the manufacturer shall be notified.

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[1] A complete description of the American Standard Pipe Thread is contained in the Pipe Thread Standard prepared under the sponsorship of the American Gas Association and the American Society of Mechanical Engineers and approved as American Standard by the American Engineering Standards Committee.

STANDARD SPECIFICATIONS
FOR
STAYBOLT, ENGINE BOLT AND EXTRA REFINED WROUGHT-IRON BARS.[1]

Serial Designation: A 84 – 21.

These specifications are issued under the fixed designation A 84; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1921.

Material Covered.

1. (*a*) These specifications cover three grades of Bar Iron:

Grade A—Staybolt Iron.
Grade B—Engine Bolt Iron.
Grade C—Extra Refined Wrought-Iron Bars.

I. MANUFACTURE.

Process.

2. *Grade A*.—The iron shall be rolled from a bloom, slab pile or box pile made wholly from reworked all-pig puddled iron or reworked knobbled charcoal iron. The puddle mixture and the component parts of the bloom, slab pile or box pile shall be free from any admixture of iron scrap or steel.

Grades B and C.—The iron shall be made wholly from all-pig puddled iron and shall be free from any admixture of iron scrap or steel.

3. (*a*) *Bloom*.—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

(*b*) *Slab Pile*.—A slab pile is built up wholly of flat bars of iron of the full length of the pile.

(*c*) *Box Pile*.—A box pile is a pile, the sides, top and bottom of which are formed by four flat bars and the interior of which consists of a number of small bars the full length of the pile.

(*d*) *Iron Scrap*.—This term applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

II. CHEMICAL PROPERTIES AND TESTS.

4. *Grade A*.—At the option of the purchaser and when so specified the iron shall conform to the following requirements as to chemical composition:

Manganese..................not over 0.10 per cent.

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[1] These specifications are a consolidation of three specifications: Specifications for Staybolt Iron (former Serial Designation: A 39 - 18; adopted, 1910; revised 1912, 1914, 1918 1921); Specifications for Engine Bolt Iron (former Serial Designation: A 40 - 18; adopted 1912; revised 1913, 1918, 1921); Specifications for Extra Refined Wrought-Iron Bars (former Serial Designation: A 79 - 19T; proposed as tentative, 1919; adopted in amended form, 1921).

Check Analysis.

5. (*a*) An analysis may be made by the purchaser from a broken test specimen representing each lot as specified in Section 11 (*a*). The chemical composition thus determined shall conform to the requirement specified in Section 4.

(*b*) Drillings for analysis shall be so taken as to represent the entire cross-section of the specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests

6. (*a*) The iron shall conform to the following requirements as to tensile properties:

		GRADE A.	GRADE B.	GRADE C.
Tensile strength, lb. per sq. in.	$1\frac{1}{4}$ sq. in. and under in sectional area..	48 000 – 52 000	49 000 – 53 000	48 000 – 54 000
	Over $1\frac{1}{4}$ sq. in. in sectional area........	....	47 000 – 53 000	48 000 – 54 000
Yield point, lb. per sq. in.	$1\frac{1}{4}$ sq. in. and under in sectional area..	0.6 tens. str.	0.6 tens. str.	0.6 tens. str.
	Over $1\frac{1}{4}$ sq. in. to 4 sq. in., incl., in sectional area..	....	0.55 "	0.55 "
	Over 4 sq. in. in sectional area.......	....	0.5 "	0.5 "
Elongation in 8 in., min., per cent.......		30	25	25
Reduction of area, min., per cent.......		48	40	37

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Tensile Properties.

7. *Grade C.*—For material over 4 sq. in. in sectional area, the following deductions from the minimum requirements specified in Section 6 (*a*) shall be made for each square inch of nominal sectional area above 4 sq. in.:

Tensile strength.............250 lb., but not under 46 000 lb.
Elongation...................0.5 per cent, but not under 22 per cent
Reduction of area............1.0 " " " " 32 "

Bend Tests.

8. (*a*) Cold-Bend Tests:

Grade A.—The test specimen shall withstand being bent cold through 180 deg. flat on itself in both directions, without fracture on the outside of the bent portions.

Grade B.—The test specimen shall withstand being bent cold through 180 deg. around a pin the diameter of which is equal to the diameter of the specimen, without fracture on the outside of the bent portion.

Grade C.—Cold-bend tests will be made only on bars having a nominal sectional area of 4 sq. in. or under, in which case the test specimen shall withstand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to the thickness of the specimen.

(*b*) Hot-Bend Tests:

Grades B and C.—The test specimen when heated to a temperature between 1700 and 1800° F. shall withstand being bent through 180 deg. flat on itself without fracture on the outside of the bent portion.

(*c*) Nick-Bend Tests:

Grades B and C.—The test specimen when nicked 25 per cent around with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter of the specimen, and broken, shall show a wholly fibrous fracture.

(*d*) Bend tests may be made by pressure or by blows.

Etch Tests.[1]

9. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material as follows:

Grade A.—The material to have been rolled from a bloom, slab pile or box pile and to be free from steel.

Grades B and C.—The material to be free from steel.

Test Specimens.

10. (*a*) Tension and bend test specimens shall be of the full section of material as rolled, if possible. Otherwise, the specimens shall be machined from the material as rolled; the axis of the specimen shall be located at any point midway between the center and surface of round bars, or midway between the center and edge of flat bars, and shall be parallel to the axis of the bar.

(*b*) Etch test specimens shall be of the full section of material as rolled.

Number of Tests.

11. (*a*) All bars of a given grade and size shall be piled separately, sorted into lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof and tested as specified; but only one of these bars shall be tested as specified in Section 9.

(*b*) If any test specimen from the bars originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

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[1] A solution of two parts water, one part HCl (sp. gr. 1.20) and one part H_2SO_4 (sp. gr. 1.84) is recommended for the etch test.

IV. PERMISSIBLE VARIATIONS IN GAGE.

Variations in Gage.

12. *Grade A.*—The bars shall be truly round within 0.01 in., and shall not vary more than 0.01 in. above nor more than 0.005 in. below the specified size.

Grade B.—The bars shall conform to the standard limit gages adopted by the Master Car Builders' Association, now the American Railway Association, Mechanical Section, as given in Table I.[1]

TABLE I.—STANDARD LIMIT GAGES FOR ENGINE BOLT IRON.

Nominal Diameter of Bars, in.	Large Size, +End, in.	Small Size, −End, in.	Total Variation in.
$\frac{1}{4}$	0.2550	0.2450	0.010
$\frac{5}{16}$	0.3180	0.3070	0.011
$\frac{3}{8}$	0.3810	0.3690	0.012
$\frac{7}{16}$	0.4440	0.4310	0.013
$\frac{1}{2}$	0.5070	0.4930	0.014
$\frac{9}{16}$	0.5700	0.5550	0.015
$\frac{5}{8}$	0.6330	0.6170	0.016
$\frac{3}{4}$	0.7585	0.7415	0.017
$\frac{7}{8}$	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
$1\frac{1}{8}$	1.1350	1.1150	0.020
$1\frac{1}{4}$	1.2605	1.2395	0.021
$1\frac{3}{8}$	1.3860	1.3640	0.022
$1\frac{1}{2}$	1.5115	1.4885	0.023
$1\frac{5}{8}$	1.6370	1.6130	0.024
$1\frac{3}{4}$	1.7625	1.7375	0.025
$1\frac{7}{8}$	1.8880	1.8620	0.026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

Grade C.—The width or thickness of bars shall vary not more than 2 per cent from that specified.

V. FINISH.

Finish.

13. The bars shall be smoothly rolled and free from slivers, depressions, crop ends, seams, and evidences of being burnt.

VI. MARKING.

Marking.

14. The bars shall be stamped or otherwise marked as designated by the purchaser.

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[1] Adopted by the Master Car Builders' Association in 1883 and revised in 1911. See *Proceedings*, Master Car Builders' Assoc., Vol. 49, Part 2, pp. 956–957 (1915).

VII. INSPECTION AND REJECTION.

Inspection.

15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 15 (*b*) shall be reported within five working days from the receipt of samples.

(*c*) *Grade A*.—Bars which will not take a clean, sharp thread with dies in fair condition, or which develop defects in forging or machining, will be rejected, and the manufacturer shall be notified.

Grades B and C.—Bars which develop defects in forging or machining will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 15 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
REFINED WROUGHT-IRON BARS.

Serial Designation: A 41 – 18.

These specifications are issued under the fixed designation A 41; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1912; Revised, 1913, 1918.

I. MANUFACTURE.

Process

1. Refined wrought-iron bars shall be made wholly from puddled iron, and may consist either of new muck-bar iron or a mixture of muck-bar iron and scrap, but shall be free from any admixture of steel.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

2. (*a*) The iron shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in. (See Sections 3 and 4)	48 000
Yield point, lb. per sq. in.	25 000
Elongation in 8 in., per cent (See Section 5)	22

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Tensile Strength

3. For material over 4 sq. in. in sectional area, a reduction of 500 lb. per sq. in. from the tensile strength specified in Section 2 will be permitted for each additional 2 sq. in., and a proportionate amount of reduction for fractional parts thereof; provided that the tensile strength shall not be less than 45,000 lb. per sq. in.

Permissible Variations in Tensile Strength.

4. Twenty per cent of the test specimens representing one size may show tensile strengths 1000 lb. per sq. in. under or 5000 lb. per sq. in. over that specified in Sections 2 and 3; but no specimen shall show a tensile strength less than 45,000 lb. per sq. in.

Permissible Variations in Elongation.

5. Twenty per cent of the test specimens representing one size may show the following percentages of elongation in 8 in.:

ROUND BARS.

½ in. or over, tested as rolled	20 per cent
Under ½ in., " " "	16 "
Reduced by machining	18 "

FLAT BARS.

⅜ in. or over, tested as rolled	18 per cent
Under ⅜ in., " " "	16 "
Reduced by machining	16 "

Bend Tests.

6. (*a*) *Cold-bend Tests.*—Cold-bend tests will be made only on bars having a nominal sectional area of 4 sq. in. or under, in which case the test specimen shall bend cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to twice the diameter or thickness of the specimen.

(*b*) *Hot-bend Tests.*—The test specimen, when heated to a temperature between 1700° and 1800° F., shall bend through 180 deg. without fracture on the outside of the bent portion, as follows: For round bars under 2 sq. in. in section, flat on itself; for round bars 2 sq. in. or over in section and for all flat bars, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

(*c*) *Nick-bend Tests.*—The test specimen, when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen, and broken, shall show not more than 10 per cent of the fractured surface to be crystallin.

(*d*) Bend tests may be made by pressure or by blows.

Etch Tests.[1]

7. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to be free from steel.

Test Specimens

8. (*a*) Tension and bend test specimens shall be of the full section of material as rolled, if possible. Otherwise, the specimens shall be machined from the material as rolled; the axis of the specimen shall be located at any point midway between the center and surface of round bars, or midway between the center and edge of flat bars, and shall be parallel to the axis of the bar.

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[1] A solution of two parts water, one part HCl (sp. gr. 1.20) and one part H_2SO_4 (sp. gr. 1.84) is recommended for the etch test.

(*b*) Etch test specimens shall be of the full section of material as rolled.

Number of Tests.

9. (*a*) All bars of one size shall be piled separately. One bar from each 100 or fraction thereof will be selected at random and tested as specified.

(*b*) If any test specimen from the bar originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

TABLE I.—STANDARD LIMIT GAGES.

Nominal Diameter of Bars, in.	Large Size, +End, in.	Small Size, −End, in.	Total Variation, in.
$\frac{1}{4}$	0.2550	0.2450	0.010
$\frac{5}{16}$	0.3180	0.3070	0.011
$\frac{3}{8}$	0.3810	0.3690	0.012
$\frac{7}{16}$	0.4440	0.4310	0.013
$\frac{1}{2}$	0.5070	0.4930	0.014
$\frac{9}{16}$	0.5700	0.5550	0.015
$\frac{5}{8}$	0.6330	0.6170	0.016
$\frac{3}{4}$	0.7585	0.7415	0.017
$\frac{7}{8}$	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
$1\frac{1}{8}$	1.1350	1.1150	0.020
$1\frac{1}{4}$	1.2605	1.2395	0.021
$1\frac{3}{8}$	1.3860	1.3640	0.022
$1\frac{1}{2}$	1.5115	1.4885	0.023
$1\frac{5}{8}$	1.6370	1.6130	0.024
$1\frac{3}{4}$	1.7625	1.7375	0.025
$1\frac{7}{8}$	1.8880	1.8620	0.026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

III. PERMISSIBLE VARIATIONS IN GAGE.

Permissible Variations.

10. (*a*) Round bars shall conform to the standard limit gages adopted by the Master Car Builders' Association, now the American Railway Association, Mechanical Section, as given in Table I.[1]

(*b*) The width or thickness of flat bars shall not vary more than 2 per cent from that specified.

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[1] Adopted by the Master Car Builders' Association in 1883 and revised in 1911. See *Proceedings*, Master Car Builders' Assoc., Vol. 49, Part 2, pp. 956–957 (1915).

IV. FINISH.

11. The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends, and evidences of being burnt. **Finish.**

V. INSPECTION AND REJECTION.

12. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment. **Inspection.**

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. (*a*) All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified. **Rejection.**

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 12 (*b*) shall be reported within five working days from the receipt of samples.

14. Samples tested in accordance with Section 12 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS
FOR
WROUGHT-IRON PLATES.

Serial Designation: A 42 – 18.

These specifications are issued under the fixed designation A 42; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1913; Revised, 1918.

Material Covered. 1. These specifications cover two classes of wrought-iron plates, as determined by the kind of material used in their manufacture, namely:

Class A, as defined in Section 2 (*b*);
Class B, as defined in Section 2 (*c*).

I. MANUFACTURE.

Process. 2. (*a*) All plates shall be rolled from piles entirely free from any admixture of steel.

(*b*) Piles for Class A plates shall be made from puddle bars made wholly from pig iron and such scrap as emanates from rolling the plates.

(*c*) Piles for Class B plates shall be made from puddle bars made wholly from pig iron or from a mixture of pig iron and cast-iron scrap, together with wrought-iron scrap.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 3. (*a*) The plates shall conform to the following minimum requirements as to tensile properties:

Properties Considered.	Class A.		Class B.	
	6 in. to 24 in., incl., in width.	Over 24 in. to 90 in., incl., in width.	6 in. to 24 in., incl., in width.	Over 24 in. to 90 in., incl., in width.
Tensile strength, lb. per sq. in.	49 000	48 000	48 000	47 000
Yield point, lb. per sq. in.	26 000	26 000	26 000	26 000
Elongation in 8 in., per cent	16	12	14	10

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Elongation.

4. For plates under $\frac{7}{16}$ in. in thickness, a deduction of 1 from the percentages of elongation specified in Section 3 shall be made for each decrease of $\frac{1}{16}$ in. in thickness below $\frac{7}{16}$ in.

Bend Tests.

5. (*a*) *Cold-bend Tests.*—The test specimen shall bend cold through 90 deg. without fracture on the outside of the bent portion, as follows: For Class A plates, around a pin the diameter of which is equal to $1\frac{1}{2}$ times the thickness of the specimen; and for Class B plates, around a pin the diameter of which is equal to 3 times the thickness of the specimen.

(*b*) *Nick-bend Tests.*—The test specimen, when nicked on one side and broken, shall show for Class A plates a wholly fibrous fracture, and for Class B plates, not more than 10 per cent of the fractured surface to be crystallin.

Test Specimens.

6. Tension and bend test specimens shall be taken from the finished plates and shall be of the full thickness of plates as rolled. The longitudinal axis of the specimen shall be parallel to the direction in which the plates are rolled.

Number of Tests.

7. (*a*) One tension, one cold-bend and one nick-bend test shall be made for each variation in thickness of $\frac{1}{8}$ in. and not less than one test for every ten plates as rolled.

(*b*) If any test specimen fails to conform to the requirements specified by reason of an apparent local defect, a retest shall be made. If the retest also fails, the plates represented by such test will be rejected.

III. FINISH.

Finish.

8. The plates shall be straight, smooth and free from cinder spots and holes, injurious flaws, buckles, blisters, seams and laminations.

IV. MARKING.

Marking.

9. The plates shall be stamped or otherwise marked as designated by the purchaser.

V. INSPECTION AND REJECTION.

Inspection.

10. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the plates ordered. The manufacturer shall afford the inspector, free of cost, all

reasonable facilities to satisfy him that the plates are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of plates at his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. Unless otherwise specified, any rejection based on tests made in accordance with Section 10 (*b*) shall be reported within five working days from the receipt of samples.

Rehearing. 12. Samples tested in accordance with Section 10 (*b*), which represent rejected plates, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
WROUGHT-IRON ROLLED OR FORGED BLOOMS AND FORGINGS FOR LOCOMOTIVES AND CARS.

Serial Designation: A 73 – 18.

These specifications are issued under the fixed designation A 73; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1917; ADOPTED IN AMENDED FORM, 1918.

Material Covered. 1. These specifications cover two classes of wrought-iron blooms and forgings for locomotives and cars, as determined by the kind of material used in their manufacture, namely:

Class A, as defined in Section 2 (*a*);
Class B, as defined in Section 2 (*b*).

I. MANUFACTURE.

Material. 2. (*a*) *Class A.*—Blooms and forgings of class A shall be made wholly from puddled pig iron. The puddle mixture and the component parts of the piles from which the blooms and forgings are made, shall be free from any admixture of iron scrap or steel. The term "iron scrap" applies only to foreign or bought scrap, and does not include the manufacturer's own scrap from the same product and of equal quality.

(*b*) *Class B.*—Blooms and forgings of class B shall be made from selected No. 1 wrought-iron scrap, or a mixture of such scrap and the puddled iron described in Paragraph (*a*).

Process. 3. Cross piling will not be permitted in either class of forging. In the final pile for the bloom or forging, all bars and slabs shall be of the full length of the pile.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. The iron shall conform to the following requirement as to chemical composition:

	CLASS A	CLASS B
Manganese, max., per cent	0.07	0.15

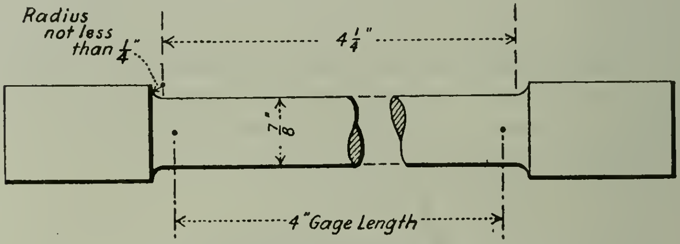
Check Analyses. 5. (*a*) An analysis may be made by the purchaser from each specimen used for the tension test. The chemical composition thus determined shall conform to the requirement specified in Section 4.

(*b*) Drillings or chips for analysis shall be so taken as to represent the full cross-section of the specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tensile Tests. 6. (*a*) The iron shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45 000
Yield point, lb. per sq. in.	0.5 tens. str.
Elongation in 4 in., per cent	22
Reduction of area, per cent	30



Note:— The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*b*) The fracture shall be free from crystallization.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{8}$ in. per minute.

Etch Tests.[1] 7. The entire cross-section of the prolongation of the bloom or forging shall be ground or polished, and shall show no seams or flaws of injurious character. It shall then be etched and, in class A blooms or forgings, shall show freedom from steel.

Tension Test Specimens. 8. (*a*) Tension test specimens shall be taken from a full-size prolongation of the bloom or forging. The axis of the specimen shall be located at any point midway between the center and surface of the bloom or forging, and shall be parallel to the axis of the bloom or forging.

(*b*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

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[1] A solution of two parts water, one part HCl (sp. gr. 1.20) and one part H_2SO_4 (sp. gr. 1.84) is recommended for the etch test.

Number of Tests. 9. The number of tests and retests, if necessary, shall be agreed upon by the manufacturer and the purchaser.

IV. WORKMANSHIP AND FINISH.

Workmanship. 10. The blooms and forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish. 11. The blooms and forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 12. Identification marks shall be legibly stamped on each bloom or forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION.

Inspection. 13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the blooms or forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the blooms or forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the blooms or forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Blooms and forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 15. Samples tested in accordance with Section 13 (*b*), which represent rejected blooms or forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests the manufacturer may make claim for a rehearing within that time.

STANDARD DEFINITIONS
OF
TERMS RELATING TO WROUGHT-IRON SPECIFICATIONS.

Serial Designation: A 81 – 21.

These definitions are issued under the fixed designation A 81; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1920; ADOPTED, 1921.

Puddling.—The process of making wrought iron by oxidizing and removing most of the silicon, carbon, manganese and phosphorus contained in pig iron in a reverberatory furnace. "Puddling" formerly was applied only to the practice of employing refined pig iron, and "Pig Boiling" was the name applied when unrefined pig iron was used, but now this distinction is not generally made as the pig iron is seldom refined. Puddling as practiced to-day is really pig boiling.

Bushelling.—The process of heating to a welding heat in a reverberatory furnace, miscellaneous iron, steel or a mixture of iron and steel scrap cut into small pieces.

Fagoting.—The making of a "Fagot" or "Box" consisting of sides and bottom made of muck or scrap bar, the interior of which is filled with miscellaneous small iron scrap or a mixture of small iron and steel scrap.

Muck Bar or Puddled Bar.—Bar rolled from puddled balls, made wholly from puddled pig iron.

Common Iron.—Iron made from rerolled scrap, no attempt being made to separate the iron and steel scrap.

Merchant Bar Iron.—Iron rolled from miscellaneous scrap, or from a box pile or fagot made of scrap bars and miscellaneous scrap or bushelled bars and miscellaneous scrap.

Refined Bar Iron or Refined Wrought-Iron Bars.—Iron rolled from muck bar pile, the muck bar being rolled from all puddled pig iron or rolled from a box pile of muck bars and wrought scrap free from steel; the bars to be the full length of the pile.

Double Refined Iron.—Iron made by cutting refined iron bars, piling them in either a slab pile or box pile, heating them and rerolling into finished bars.

STANDARD SPECIFICATIONS
FOR
FOUNDRY PIG IRON.[1]

Serial Designation: A 43–09.

These specifications are issued under the fixed designation A 43; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1904; Revised, 1909.

Percentages and Variations.

In order that there may be uniformity in grading, the following percentages and variations shall be used.[2]

Silicon.		*Sulfur.*		*Total Carbon.*	
Per cent.	Code.	Per cent.	Code.	Per cent.	Code.
1.00	La	0.04	Sa	3.00	Ca
1.50	Le	0.05	Se	3.20	Ce
2.00	Li	0.06	Si	3.40	Ci
2.50	Lo	0.07	So	3.60	Co
3.00	Lu	0.08	Su	3.80	Cu
3.50	Ly	0.09	Sy		
		0.10	Sh		
(0.25 allowed either way.)		(Maximum.)		(Minimum.)	

Manganese.		*Phosphorus.*	
Per cent.	Code.	Per cent.	Code.
0.20	Ma	0.20	Pa
0.40	Me	0.40	Pe
0.60	Mi	0.60	Pi
0.80	Mo	0.80	Po
1.00	Mu	1.00	Pu
1.25	My	1.25	Py
1.50	Mh	1.50	Ph
(0.20 allowed either way.)		(0.15 allowed either way.)	

Illustration of the use of above coding: The word Li-se-ca-mo-pi indicates

Sil.	Sul.	Carb.	Mang.	Phos.
2.00	0.05	3.00	0.80	0.60

with variations as allowed.

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[1] It is recommended that foundry pig iron be bought by analysis, and that when so bought these Standard Specifications be used.

[2] These specifications do not advise that all five elements be specified in all contracts for pig iron, but do recommend that when these elements are specified, the given percentages shall be used.

Percentages of any element specified half way between the above shall be designated by the addition of the letter X to the next lower symbol.

Example.—PeX indicates Phosphorus 0.50 with "allowed" variations (0.15) up and down.

In the case of phosphorus and manganese, the percentages may be used as maximum or minimum figures, but unless so specified they will be considered to include the variations above given.

SAMPLING AND ANALYSIS.

Each car load, or its equivalent, shall be considered as a unit in sampling.

One sample shall be taken to every four tons in the car, and shall be so chosen from different parts of the car as to represent as nearly as possible the average quality of the iron.

Drillings shall be taken so as to fairly represent the composition of the pig as cast.

An equal weight of the drillings from each pig shall be thoroughly mixed to make up the sample for analysis.

In case of dispute, the sampling and analysis shall be made by an independent chemist, mutually agreed upon, if practicable, at the time the contract is made.

It is recommended that the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (Serial Designation: A 64) of the American Society for Testing Materials, be used for analysis. Gravimetric methods shall be used for the analysis of sulfur, unless otherwise specified in the contract.

The cost of re-sampling and re-analysis shall be borne by the party in error.

BASE OR QUOTING PRICE.

For market quotations, an iron of 2.00 per cent in silicon (with variations of 0.25 either way) and 0.05 per cent in sulfur (maximum) shall be taken as the base.

THE AMERICAN FOUNDRYMEN'S ASSOCIATION SUGGESTS THE FOLLOWING CLAUSES FOR THE PURPOSE OF ADJUSTING DISPUTES BETWEEN BUYER AND SELLER.

Base Table.—The following table may be filled out, and may become a part of the contract. "B," or Base, represents the price agreed upon for a pig iron running 2.00 per cent in silicon (with allowed variation of 0.25 either way) and under 0.05 per cent in sulfur; "C" is a constant differential to be determined at the time the contract is made.

This table is for settling any differences which may arise in filling a contract, as explained under penalties and allowances, and may be used to regulate the price of a grade of pig iron which the purchaser desires, and the seller agrees, to substitute for the one originally specified.

Silicon percentages allow 0.25 variation either way. Sulfur percentages are maximum.

Sulfur, per cent.	*Silicon, per cent.*									
	3.25	3.00	2.75	2.50	2.25	2.00	1.75	1.50	1.25	1.00
0.04....	B+6C	B+5C	B+4C	B+3C	B+2C	B+1C	B	B−1C	B−2C	B−3C
0.05 ...	B+5C	B+4C	B+3C	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C
0.06....	B+4C	B+3C	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C
0.07....	B+3C	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C
0.08....	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C	B−7C
0.09....	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C	B−7C	B−8C
0.10....	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C	B−7C	B−8C	B−9C

Penalties.—In case the iron, when delivered, does not conform to the specifications, the buyer shall have the option of either refusing the iron, or accepting it on the basis shown in the above table, which must be filled out at the time the contract is made.

Allowances.—In case the furnace cannot, for any good reason, deliver the iron as specified at the time delivery is due, the purchaser may at his option accept any other analysis which the furnace can deliver, the price to be determined by the base table above, which must be filled out at the time the contract is made.

STANDARD SPECIFICATIONS
FOR
CAST-IRON PIPE AND SPECIAL CASTINGS.

Serial Designation: A 44 – 04.

These specifications are issued under the fixed designation A 44; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1904.

Description of Pipes.

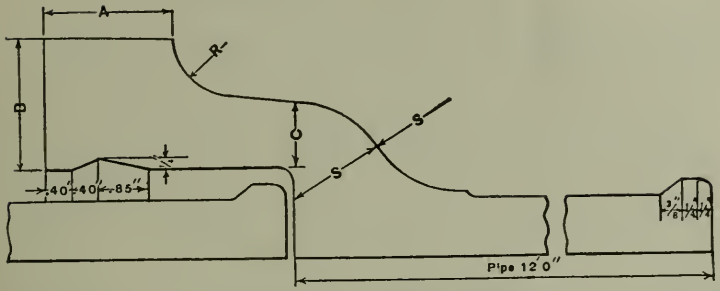
Section 1. The pipes shall be made with hub and spigot joints, and shall accurately conform to the dimensions given in Tables I and II. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least 12 ft. in length, exclusive of socket. For pipes of each size from 4 in. to 24 in., inclusive, there shall be two standards of outside diameter, and for pipes from 30 in. to 60 in., inclusive, there shall be four standards of outside diameter, as shown by Table II.

All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 in. from each end of the pipe so as to obtain the required standard thickness and weight for each size and class of pipe.

Pipes whose standard thickness and weight are intermediate between the classes in Table II shall be made of the same outside diameter as the next heavier class. Pipes whose standard thickness and weight are less than shown by Table II shall be made of the same outside diameter as the Class A pipes, and pipes whose thickness and weight are more than shown by Table II shall be made of the same outside diameter as the Class D pipes.

For pipes 4 in. to 12 in., inclusive, one class of special castings shall be furnished, made from Class D pattern. Those

TABLE I.—GENERAL DIMENSIONS OF PIPES.



Nominal Diam., in.	Classes.	Actual Outside Diam., in.	DIAM. OF SOCKETS.		DEPTH OF SOCKETS.		A	B	C
			Pipe, in.	Special Castings, in.	Pipe, in.	Special Castings, in.			
4	A—B	4.80	5.60	5.70	3.50	4.00	1.5	1.30	0.65
4	C—D	5.00	5.80	5.70	3.50	4.00	1.5	1.30	0.65
6	A—B	6.90	7.70	7.80	3.50	4.00	1.5	1.40	0.70
6	C—D	7.10	7.90	7.80	3.50	4.00	1.5	1.40	0.70
8		9.05	9.85	10.00	4.00	4.00	1.5	1.50	0.75
8	C—D	9.30	10.10	10.00	4.00	4.00	1.5	1.50	0.75
10	A—B	11.10	11.90	12.10	4.00	4.00	1.5	1.50	0.75
10	C—D	11.40	12.20	12.10	4.00	4.00	1.5	1.60	0.80
12	A—B	13.20	14.00	14.20	4.00	4.00	1.5	1.60	0.80
12	C—D	13.50	14.30	14.20	4.00	4.00	1.5	1.70	0.85
14	A—B	15.30	16.10	16.10	4.00	4.00	1.5	1.70	0.85
14	C—D	15.65	16.45	16.45	4.00	4.00	1.5	1.80	0.90
16	A—B	17.40	18.40	18.40	4.00	4.00	1.75	1.80	0.90
16	C—	17.80	18.80	18.80	4.00	4.00	1.75	1.90	1.00
18	A—B	19.50	20.50	20.50	4.00	4.00	1.75	1.90	0.95
18	C—D	19.92	20.92	20.92	4.00	4.00	1.75	2.10	1.05
20	A—B	21.60	22.60	22.60	4.00	4.00	1.75	2.00	1.00
20	C—D	22.06	23.06	23.06	4.00	4.00	1.75	2.30	1.15
24	A—B	25.80	26.80	26.80	4.00	4.00	2.00	2.10	1.05
24	C—D	26.32	27.32	27.32	4.00	4.00	2.00	2.50	1.25
30	A	31.74	32.74	32.74	4.50	4.50	2.00	2.50	1.15
30	B	32.00	33.00	33.00	4.50	4.50	2.00	2.30	1.15
30	C	32.40	33.40	33.40	4.50	4.50	2.00	2.60	1.32
30	D	32.74	33.74	33.74	4.50	4.50	2.00	3.00	1.50
36	A	37.96	38.96	38.96	4.50	4.50	2.00	2.50	1.25
36	B	38.30	39.30	39.30	4.50	4.50	2.00	2.80	1.40
36	C	38.70	39.70	39.70	4.50	4.50	2.00	3.10	1.60
36	D	39.16	40.16	40.16	4.50	4.50	2.00	3.40	1.80
42	A	44.20	45.20	45.20	5.00	5.00	2.00	2.80	1.40
42	B	44.55	45.50	45.50	5.00	5.00	2.00	3.00	1.50
42	C	45.10	46.10	46.10	5.00	5.00	2.00	3.40	1.75
42	D	45.58	46.58	46.58	5.00	5.00	2.00	3.80	1.95
48	A	50.50	51.50	51.50	5.00	5.00	2.00	3.00	1.50
48	B	50.80	51.80	51.80	5.00	5.00	2.00	3.30	1.65
48	C	51.40	52.40	52.40	5.00	5.00	2.00	3.80	1.95
48	D	51.98	52.98	52.98	5.00	5.00	2.00	4.20	2.20
54	A	56.66	57.66	57.66	5.50	5.50	2.25	3.20	1.60
54	B	57.10	58.10	58.10	5.50	5.50	2.25	3.60	1.80

TABLE I.—(CONTINUED.)

Nominal Diam., in.	Classes.	Actual Outside Diam., in.	DIAM. OF SOCKETS.		DEPTH OF SOCKETS.		A	B	C
			Pipe, in.	Special Castings, in.	Pipe, in.	Special Castings, in.			
54	C	57.80	58.80	58.80	5.50	5.50	2.25	4.00	2.15
54	D	58.40	59.40	59.40	5.50	5.50	2.25	4.40	2.45
60	A	62.80	63.80	63.80	5.50	5.50	2.25	3.40	1.70
60	B	63.40	64.40	64.40	5.50	5.50	2.25	3.70	1.90
60	C	64.20	65.20	65.20	5.50	5.50	2.25	4.20	2.25
60	D	64.82	65 82	65.82	5.50	5.50	2.25	4.70	2.60

having spigot ends shall have outside diameters of spigot ends midway between the two standards of outside diameter as shown by Table II, and shall be tapered back for a distance of 6 in. For pipes from 14 in. to 24 in., inclusive, two classes of special castings shall be furnished, Class B special castings with Classes A and B pipes, and Class D special castings with Classes C and D pipes, the former to be stamped "AB" and the latter to be stamped "CD." For pipes 30 in. to 60 in., inclusive, four classes of special castings shall be furnished, one for each class of pipe, and shall be stamped with the letter of the class to which they belong.

ALLOWABLE VARIATION IN DIAMETER OF PIPES AND SOCKETS.

SECTION 2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gages, and no pipe will be received which is defective in joint room from any cause. The diameters of the sockets and the outside diameters of the bead ends of the pipes shall not vary from the standard dimensions by more than 0.06 in. for pipes 16 in. or less in diameter; 0.08 in. for 18-in., 20-in. and 24-in. pipes; 0.10 in. for 30-in., 36-in. and 42-in. pipes; 0.12 in. for 48-in. pipes; and 0.15 in. for 54-in. and 60-in. pipes.

ALLOWABLE VARIATION IN THICKNESS.

SECTION 3. For pipes whose standard thickness is less than 1 in., the thickness of metal in the body of the pipe shall not be more than 0.08 in. less than the standard thickness; and for pipes whose standard thickness is 1 in. or more, the variation shall not exceed 0.10 in., except that for spaces not exceeding 8 in. in length in any direction, variations from the standard thickness of 0.02 in. in excess of the allowance above given shall be permitted.

TABLE II.—STANDARD THICKNESSES AND WEIGHTS OF CAST IRON PIPE.

Nominal Inside Diameter, in.	Class A. 100 ft. head. 43 lb. pressure.			Class B. 200 ft. head. 86 lb. pressure.			Class C. 300 ft. head. 130 lb. pressure.			Class D. 400 ft. head. 173 lb. pressure.			Nominal Inside Diameter, in.
	Thickness, in.	Weight per		Thickness, in.	Weight per		Thickness, in.	Weight per		Thickness, in.	Weight per		
		Foot.	Length.		Foot.	Length.		Foot.	Length.		Foot.	Length.	
4	0.42	20.0	240	0.45	21.7	260	0.48	23.3	280	0.52	25.0	300	4
6	0.44	30.8	370	0.48	33.3	400	0.51	35.8	430	0.55	38.3	460	6
8	0.46	42.9	515	0.51	47.5	570	0.56	52.1	625	0.60	55.8	670	8
10	0.50	57.1	685	0.57	63.8	765	0.62	70.8	850	0.68	76.7	920	10
12	0.54	72.5	870	0.62	82.1	985	0.68	91.7	1 100	0.75	100.0	1 200	12
14	0.57	89.6	1 075	0.66	102.5	1 230	0.74	116.7	1 400	0.82	129.2	1 550	14
16	0.60	108.3	1 300	0.70	125.0	1 500	0.80	143.8	1 725	0.89	158.3	1 900	16
18	0.64	129.2	1 550	0.75	150.0	1 800	0.87	175.0	2 100	0.96	191.7	2 300	18
20	0.67	150.0	1 800	0.80	175.0	2 100	0.92	208.3	2 500	1.03	229.2	2 750	20
24	0.76	204.2	2 450	0.89	233.3	2 800	1.04	279.2	3 350	1.16	306.7	3 680	24
30	0.88	291.7	3 500	1.03	333.3	4 000	1.20	400.0	4 800	1.37	450.0	5 400	30
36	0.99	391.7	4 700	1.15	454.2	5 450	1.36	545.8	6 550	1.58	625.0	7 500	36
42	1.10	512.5	6 150	1.28	591.7	7 100	1.54	716.7	8 600	1.78	825.0	9 900	42
48	1.26	666.7	8 000	1.42	750.0	9 000	1.71	908.3	10 900	1.96	1 050.0	12 600	48
54	1.35	800.0	9 600	1.55	933.3	11 200	1.90	1 141.7	13 700	2.23	1 341.7	16 100	54
60	1.39	916.7	11 000	1.67	1 104.2	13 250	2.00*	1 341.7	16 100	2.38	1 583.3	19 000	60

The above weights are for 12 ft. laying lengths and standard sockets; proportionate allowance to be made for any variation therefrom.

For special castings of standard patterns a variation of 50 per cent greater than allowed for straight pipe shall be permitted.

DEFECTIVE SPIGOTS MAY BE CUT.

SECTION 4. Defective spigot ends on pipes 12 in. or more in diameter may be cut off in a lathe, and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 ft. in length, exclusive of the socket.

In case the length of a pipe differs from 12 ft., the standard weight of the pipe given in Table II shall be modified in accordance therewith.

SPECIAL CASTINGS.

SECTION 5. All special castings shall be made in accordance with the cuts and the dimensions given in the table forming a part of these specifications.

The diameters of the sockets and the external diameters of the bead ends of the special castings shall not vary from the standard dimensions by more than 0.12 in. for castings 16 in. or less in diameter; 0.15 in. for 18-in., 20-in. and 24-in. pipes; 0.20 in. for 30-in., 36-in. and 42-in. pipes; and 0.24 in. for 48-in., 54-in. and 60-in. pipes. These variations apply only to special castings made from standard patterns.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The manufacturer shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans and made of the best quality of mild steel, with hexagonal heads and nuts and sound, well-fitting threads.

MARKING.

SECTION 6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe and special casting larger than 4 in. may also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus:

1901	1901	1901
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and shall be not less than 2 in. in length and ⅛ in. in relief for pipes 8 in. in diameter and larger. For smaller sizes of pipes the letters may be 1 in. in length. The weight and the class letter shall be conspicuously painted in white on the inside of each pipe and special casting after the coating has become hard.

Allowable Percentage of Variation in Weight.

Section 7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than 5 per cent for pipes 16 in. or less in diameter, and 4 per cent for pipes more than 16 in. in diameter; and no excess above the standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than 2 per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent for pipes 12 in. or less in diameter, and 8 per cent for larger sizes, except that curves, Y-pieces and breeches pipe may be 12 per cent below the standard weight, and no excess above the standard weight of more than the above percentages for the several sizes will be paid for. These variations apply only to castings made from the standard patterns.

Quality of Iron.

Section 8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

Tests of Materials.

Section 9. Specimen bars of the metal used, each being 26 in. long by 2 in. wide and 1 in. thick, shall be made without charge as often as the engineer may direct, and, in default of definite instructions, the contractor shall make and test at least one bar from each heat or run of metal. The bars, when placed flat-wise upon supports 24 in. apart and loaded in the center, shall, for pipes 12 in. or less in diameter, support a load of 1900 lb. and show a deflection of not less than 0.30 in. before breaking; and for pipes of sizes larger than 12 in., they shall support a load of 2000 lb. and show a deflection of not less than 0.32 in. The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

CASTING OF PIPES.

SECTION 10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 in. or less in diameter shall be cast with the hub end up or down, as specified in the proposal. Pipes 18 in. or more in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

QUALITY OF CASTINGS.

SECTION 11. The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

CLEANING AND INSPECTION.

SECTION 12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

COATING.

SECTION 13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300° F. immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300° F. (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated, the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be re-coated shall first be thoroughly scraped and cleaned.

HYDROSTATIC TEST.

SECTION 14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

	20-In. Diameter and Larger, lb. per sq. in.	Less than 20-In. Diameter. lb. per sq. in.
Class A pipe....	150	300
Class B pipe....	200	300
Class C pipe....	250	300
Class D pipe....	300	300

WEIGHING.

SECTION 15. The pipes and special castings shall be weighed for payment under the supervision of the engineer after the application of the coal-tar pitch varnish. If desired by the engineer the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made on the basis of a ton of 2000 lb.

CONTRACTOR TO FURNISH MEN AND MATERIALS.

SECTION 16. The contractor shall provide all tools, testing machines, materials and men necessary for the required testing, inspection and weighing at the foundry of the pipes and special castings; and, should the purchaser have no inspector at the works, the contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the tests upon the test bars.

POWER OF ENGINEER TO INSPECT.

SECTION 17. The engineer shall be at liberty at all times to inspect the material at the foundry, and the molding, casting and coating of the pipes and special castings. The forms, sizes, uniformity and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipes or other castings which are not in conformity with the specifications or drawings.

INSPECTOR TO REPORT.

SECTION 18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

CASTINGS TO BE DELIVERED SOUND AND PERFECT.

SECTION 19. All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipe or other castings which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered until the final completion and adjustment of the contract, provided, however, that the contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation or at any time after they receive the coating.

DEFINITION OF THE WORD "ENGINEER."

SECTION 20. Wherever the word "engineer" is used herein, it shall be understood to refer to the engineer or inspector acting for the purchaser and to his properly authorized agents, limited by the particular duties intrusted to them.

STANDARD SPECIFICATIONS
FOR
CAST-IRON SOIL PIPE AND FITTINGS.

Serial Designation: A 74 – 18.

These specifications are issued under the fixed designation A 74; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted, 1918.

I. MANUFACTURE.

Cast Iron.

1. The cast iron from which the pipe and fittings are made shall be of such composition, and the conditions of manufacture so maintained, that the castings will be of uniform physical character, close-grain, and not hard, brittle nor difficult to cut with file or chisel.

Coating for Cast Iron.

2. (*a*) When pipe or fittings are to be coated, coal-tar pitch shall be used, which shall contain sufficient oil to make a smooth coating. The pitch shall be tough and tenacious when cold, and not brittle nor having any tendency to scale.

(*b*) The varnish shall be heated to about 300° F. and shall remain at this temperature during the time the casting is immersed.

(*c*) Each casting shall be heated to a uniform temperature of about 300° F. immediately before it is dipped, and shall possess this temperature at the time it is put in the bath.

(*d*) Each casting shall remain in the bath at least two minutes.

(*e*) Fresh pitch and oil shall be added when necessary to keep the mixture of the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch whenever the accumulation of sand or carbonaceous matter renders this desirable, as can be seen by the solids adhering to the under side or lower ends of the castings.

(*f*) After being coated, the pipe and fittings shall be carefully drained of the surplus varnish.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. Drillings taken from the fractured end of the arbitration st bar shall not contain over 0.10 per cent of sulfur.

III. PHYSICAL PROPERTIES AND TESTS.

Transverse Tests. 4. The transverse test specimens (arbitration test bars) specified in Section 7, when placed horizontally upon supports 12 in. apart and tested under a centrally applied load, shall conform to the following minimum requirements:

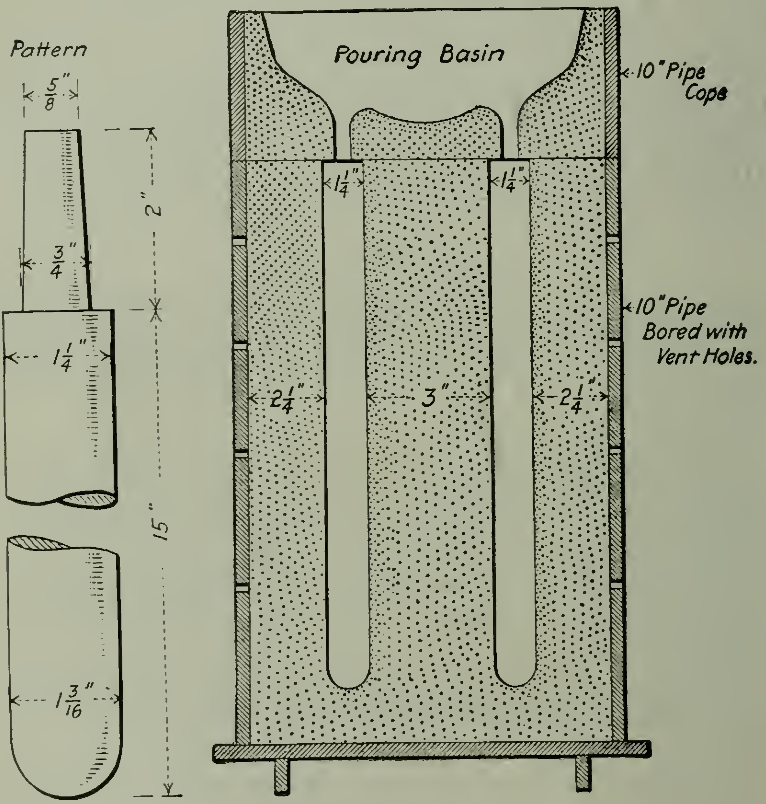


FIG. 1.—Mold for Arbitration Test Bar.

Average load at center, lb	2500
Average deflection at center, in	0.10

Hydrostatic Tests. 5. All pipe shall be tested to a hydrostatic pressure of not less than 50 lb. per sq. in. before coating. Any casting showing defects under this hydrostatic test shall be promptly broken and returned to the cupola.

Mold for Test Specimens. 6. The form and dimensions of the mold for the arbitration test bar shall be in accordance with Fig. 1. The bottom of the bar shall be $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask shall be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried, and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

TABLE I.—WEIGHTS OF SOIL PIPE.

Size, in.	Single Hub.		Double Hub.
	Per 5-ft. Length, lb.	Per ft. including Hub, lb.	Per 5-ft. Length, lb.
2.................	27½	5½	27½
3.................	47½	9½	47½
4.................	65	13	66
5.................	85	17	86
6.................	100	20	100

Number of Specimens. 7. From each melt of metal not less than three test specimens (arbitration test bars) shall be poured, the first of which shall be poured within five minutes after the first ladle is tapped and the remainder at intervals not exceeding one hour throughout the melt.

IV. STANDARD SIZES AND WEIGHTS.

Sizes. 8. (*a*) The inside diameter of the barrel of any pipe or fittings or branch thereof shall not vary more than $\frac{1}{8}$ in. under the nominal size of pipe.

(*b*) The outside diameter of the barrel of pipe and fittings shall be $\frac{1}{2}$ in. greater than its nominal inside diameter. A variation in the outside diameter of $\frac{1}{8}$ in. over or under these figures will be permitted.

(*c*) All pipe and fittings shall be of uniform thickness of wall and present true circles at the hub and spigot ends. A variation of $\frac{1}{16}$ in. under the following dimensions will be permitted, but only when the actual weight is not less than the variation of the marked or estimated weight as given in Tables I and II:

Thickness of barrel .... $\frac{1}{4}$ in.
" " body of hub .... $\frac{5}{16}$ "
" " bead of hub .... $\frac{1}{2}$ "
" " bead of spigot end .... $\frac{7}{16}$ "

TABLE II.—WEIGHTS OF SOIL PIPE FITTINGS.

ONLY THE STAPLE FITTINGS ARE SHOWN. FROM THE DATA HEREWITH THE WEIGHTS OF OTHER FITTINGS MAY BE CALCULATED.

All values are in pounds.

Fittings.	Size of Fittings, in.														
	2	3	4	5	6	3 by 2	4 by 2	4 by 3	5 by 2	5 by 3	5 by 4	6 by 2	6 by 3	6 by 4	6 by 5
$\frac{1}{4}$ Bends, regular	$6\frac{3}{4}$	$10\frac{1}{4}$	15	19	$23\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{4}$ Bends, short sweep	$8\frac{1}{4}$	$12\frac{1}{2}$	$17\frac{3}{4}$	$22\frac{1}{2}$	$27\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{4}$ Bends, long sweep	$10\frac{1}{4}$	$15\frac{3}{4}$	22	$27\frac{1}{2}$	$33\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{5}$ Bends	$6\frac{1}{4}$	$9\frac{3}{4}$	$13\frac{3}{4}$	$17\frac{1}{2}$	$21\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{6}$ Bends	6	$9\frac{1}{4}$	13	$16\frac{1}{2}$	20	....	....	....	....	....	....	....	....	....	....
$\frac{1}{8}$ Bends	$5\frac{1}{2}$	$8\frac{1}{2}$	$12\frac{1}{4}$	$15\frac{1}{4}$	$18\frac{1}{4}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{16}$ Bends	5	$7\frac{3}{4}$	$10\frac{3}{4}$	$13\frac{1}{4}$	$15\frac{3}{4}$	....	....	....	....	....	....	....	....	....	....
Return Bends	$8\frac{3}{4}$	14	$20\frac{1}{4}$	$26\frac{1}{2}$	$33\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
Tees	$10\frac{1}{4}$	$15\frac{1}{4}$	21	$26\frac{1}{2}$	$32\frac{1}{2}$	$13\frac{1}{4}$	$16\frac{1}{2}$	$18\frac{3}{4}$	$19\frac{1}{4}$	22	$24\frac{1}{2}$	$22\frac{1}{2}$	25	$27\frac{1}{2}$	30
Tapped Tees (tapped up to 2 in.)	$8\frac{3}{4}$	....	....	....	....	$11\frac{3}{4}$	15	....	$17\frac{3}{4}$	....	....	$20\frac{1}{2}$	....	....	....
Sanitary Tees	11	$16\frac{1}{4}$	$22\frac{1}{2}$	28	$34\frac{1}{2}$	14	$17\frac{1}{4}$	$19\frac{3}{4}$	20	23	$25\frac{1}{2}$	23	26	29	$31\frac{1}{2}$
Tapped Sanitary Tees (tapped up to 2 in.)	9	....	....	....	....	12	$15\frac{1}{4}$	....	18	....	....	$21\frac{1}{4}$	....	....	....
Y Branch	11	17	24	$31\frac{1}{2}$	$39\frac{1}{2}$	14	$17\frac{1}{4}$	$20\frac{1}{2}$	20	$23\frac{1}{2}$	$27\frac{1}{2}$	23	27	31	35
$\frac{1}{2}$ Y Branch	$10\frac{1}{4}$	$15\frac{1}{2}$	$21\frac{1}{2}$	$27\frac{1}{2}$	34	$13\frac{1}{2}$	$16\frac{1}{2}$	19	$19\frac{1}{2}$	22	25	$22\frac{1}{2}$	$25\frac{1}{2}$	$28\frac{1}{2}$	31
Tapped Inverted Y Branch (tapped up to 2 in.)	$10\frac{1}{4}$	$13\frac{3}{4}$	$17\frac{1}{2}$	21	24	....	....	....	....	....	....	....	....	....	....
Inverted Y Branch	$11\frac{1}{2}$	18	$25\frac{1}{2}$	33	$41\frac{1}{2}$	15	$18\frac{3}{4}$	22	22	$25\frac{1}{2}$	$29\frac{1}{2}$	$25\frac{1}{2}$	$29\frac{1}{2}$	33	37
Combination Y and $\frac{1}{8}$ Bend	12	$18\frac{3}{4}$	27	35	$44\frac{1}{2}$	15	$18\frac{1}{4}$	$22\frac{1}{2}$	21	$25\frac{1}{2}$	$30\frac{1}{2}$	24	29	34	39
Upright Y Branch	$12\frac{1}{2}$	$19\frac{1}{2}$	28	$36\frac{1}{2}$	46	$15\frac{3}{4}$	$18\frac{3}{4}$	23	$21\frac{1}{2}$	$26\frac{1}{2}$	$31\frac{1}{2}$	$24\frac{1}{2}$	$29\frac{1}{2}$	35	40

Weights. 9. (*a*) Weights and measurements of pipe and fittings shall be taken as those of plain uncoated pipe. All weights shall be given in pounds.

(*b*) Individual lengths of pipe and fittings may weigh 5 per cent less than designated in Tables I and II, but only when the average weight of a given size and weight of pipe and fittings selected at random, is not less than that shown in Tables I and II.

(*c*) The regular length of pipe shall be such as to lay 5 ft. including hub.

(*d*) The average weights of soil pipe and fittings shall not be less than those given in Tables I and II.

V. WORKMANSHIP AND FINISH.

Character of Castings.

10. (*a*) All pipe and fittings shall be practically straight and cylindrical and fittings true to pattern. The specified sizes shall be for the inside diameter and shall conform, within the allowable variation, to the dimensions given in the tables.

(*b*) All pipe and fittings shall be carefully examined for defects and sounded with a hammer before shipment. No fillings with metal, cement or other material, or so-called "burning on" of iron will be permitted. The castings shall be sound and free from cracks, sand-holes, blow-holes and cold-shots.

VI. MARKING.

Marking.

11. All pipe and fittings shall be marked with the name of the manufacturer, or appropriate initial. Each casting shall have cast upon it the minimum or estimated weight of same as shown in Tables I and II.

VII. INSPECTION AND REJECTION.

Inspection.

12. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works, and shall be made prior to shipment, unless otherwise specified.

Rejection.

13. All pipe and fittings which fail to conform to the provisions of these specifications shall be subject to rejection.

STANDARD SPECIFICATIONS
FOR
CAST-IRON LOCOMOTIVE CYLINDERS.

Serial Designation: A 45 – 14.

These specifications are issued under the fixed designation A 45; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1911, 1914.

I. MANUFACTURE.

Process. 1. Locomotive cylinders shall be made from good quality, close-grain gray iron cast in a dry mold.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 2. Drillings taken from the fractured end of the transverse test bars shall conform to the following requirements as to chemical composition:

Phosphorus	not over 0.90 per cent
Sulfur	" " 0.12 "

Check Analyses. 3. A check analysis of drillings taken from the transverse test bar may be made by the purchaser. The phosporous and sulfur content thus determined shall conform to the requirements specified in Section 2.

III. PHYSICAL PROPERTIES AND TESTS.

Transverse Tests. 4. The transverse test specimens (arbitration test bars) specified in Section 6 (*a*), when placed horizontally upon supports 12 in. apart and tested under a centrally applied load, shall conform to the following minimum requirements:

Average load at center, lb	3 200
Average deflection at center, in	0.09

Chill Tests. 5. Before pouring, a sample of the iron shall be taken and chilled in a cast-iron mold, as specified in Section 6 (*b*). The sample shall be allowed to cool in the mold until it is dark red or almost black, when it shall be knocked out and quenched in water. This chill test specimen, on being broken, shall show a close-grain gray iron, with a well-defined border of white iron at the bottom of the fracture. The depth of the white iron shall not be less than $\frac{1}{16}$ in. as measured at the center line.

Molds for Test Specimens.

6. (*a*) *Arbitration Test Bar.*—The form and dimensions of the mold for the arbitration test bar shall be in accordance with Fig. 1. The bottom of the bar shall be $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring.

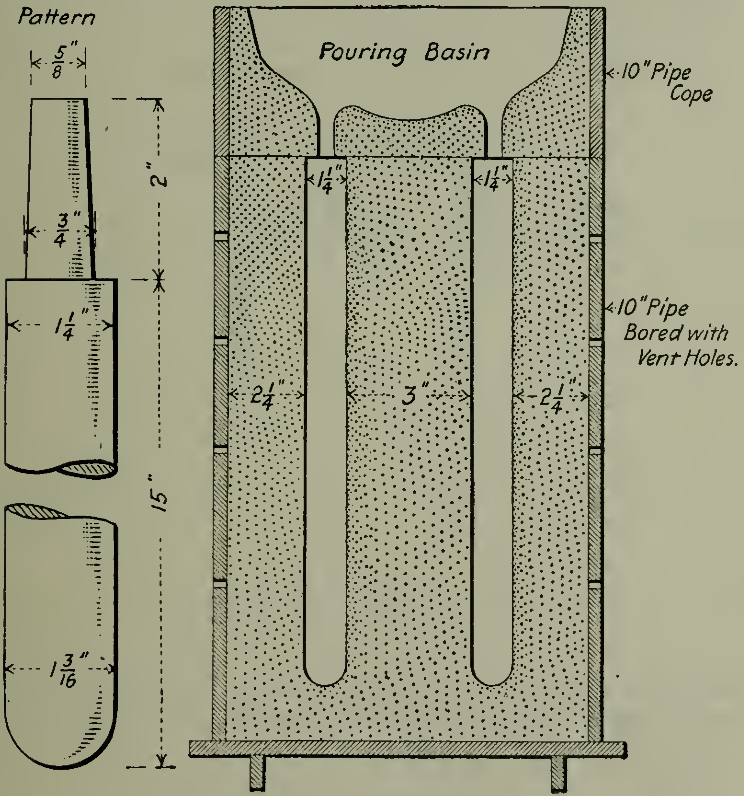


FIG. 1.—Mold for Arbitration Test Bar.

The pattern shall not be rapped before withdrawing. The flask shall be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried, and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

(*b*) *Chill Test Specimen.*—The form and dimensions of the mold for the chill test specimen shall be in accordance with Fig. 2.

Number of Tests

7. (*a*) Two arbitration test bars, cast as specified in Section 6 (*a*), shall be poured from each ladle of metal used for one or more cylinders, and tested as specified in Section 4.

(*b*) One chill test specimen, cast as specified in Section 6 (*b*), shall be poured from each ladle of metal used for one or more cylinders and broken as specified in Section 5. The chill test specimens may be cast in adjacent molds, but in such cases a space must be provided between the molds. (See Fig. 2.)

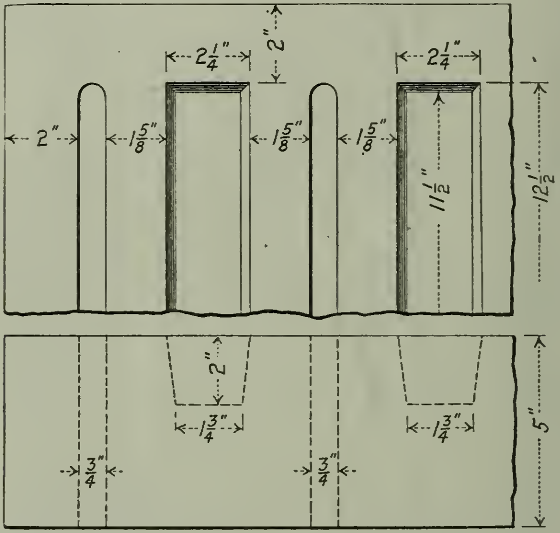


FIG. 2.—Mold for Chill Test Specimen.

IV. WORKMANSHIP AND FINISH.

Character of Castings.

8. The cylinders shall be smooth, well-cleaned, free from shrinkage cracks and from other defects sufficiently extensive to impair the value of the castings, and shall finish to the size specified by the purchaser.

V. MARKING.

Marking.

9. Marks designating the maker, the date of casting, the serial and pattern numbers and other marks specified by the purchaser, shall be cast on each cylinder in raised letters.

VI. INSPECTION AND REJECTION.

Inspection. 10. (*a*) The inspector representing the purchaser shall be given a reasonable opportunity to enable him to witness the pouring of the cylinders and test specimens, as well as to be present when physical tests are made.

(*b*) In case the inspector is not present to witness the pouring of the cylinders and test specimens, the manufacturer will make all tests required by these specifications. He will, upon demand, furnish the purchaser with a copy of the results of his tests, and will hold the transverse and chill test specimens subject to examination by the inspector. The tests made by the manufacturer shall be considered final.

(*c*) All physical tests and inspection shall be made at the place of manufacture.

Rejection. 11. Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples.

STANDARD SPECIFICATIONS
FOR
MALLEABLE CASTINGS.

Serial Designation: A 47 – 19.

These specifications are issued under the fixed designation A 47; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1915, 1919.

Material Covered. 1. These specifications cover malleable castings for railroad, motor vehicle, agricultural implement, and general machinery purposes.

I. MANUFACTURE.

Process. 2. The castings shall be produced by either the air-furnace, open-hearth, or electric-furnace process.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 3. The tension test specimens specified in Section 5 shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45 000
Elongation in 2 in., per cent	7.5

Special Tests. 4. (*a*) All castings, if of sufficient size, shall have cast thereon test lugs of a size proportional to the thickness of the casting, but not exceeding $\frac{5}{8}$ by $\frac{3}{4}$ in. in cross-section. On castings which are 24 in. or over in length, a test lug shall be cast near each end. These test lugs shall be attached to the casting at such a point that they will not interfere with the assembling of the castings, and may be broken off by the inspector.

(*b*) If the purchaser or his representative so desires, a casting may be tested to destruction. Such a casting shall show good, tough malleable iron.

Tension Test Specimens. 5. (*a*) Tension test specimens shall be of the form and dimensions shown in Fig. 1. Specimens whose mean diameter at the smallest section is less than $\frac{19}{32}$ in. will not be accepted for test.

(*b*) A set of three tension test specimens shall be cast from each melt, without chills, using heavy risers of sufficient height to secure sound bars. The specimens shall be suitably marked for identification with the melt. Each set of specimens so cast shall be placed in some one oven containing castings to be annealed.

Number of Tests. 6. (*a*) After annealing, three tension test specimens shall be selected by the inspector as representing the castings in the oven from which these specimens are taken.

(*b*) If the first specimen conforms to the specified requirements, or if, in the event of failure of the first specimen, the second and third specimens conform to the requirements, the castings in that oven shall be accepted, except that any casting may be rejected if its test lug shows that it has not been properly annealed. If either the second or third specimen fails to conform to the requirements, the entire contents of that oven shall be rejected.

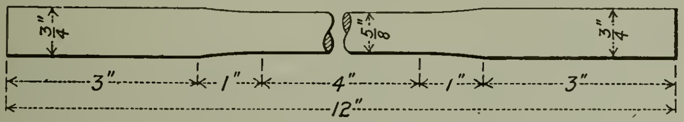


FIG. 1.

Re-annealing. 7. Any castings rejected for insufficient annealing may be re-annealed once. The re-annealed castings shall be inspected and if the remaining test lugs, or castings broken as specimens, show the castings to be thoroughly annealed, they shall be accepted; if not, they shall be finally rejected.

III. WORKMANSHIP AND FINISH.

Workmanship. 8. The castings shall conform substantially to the patterns or drawings furnished by the purchaser, and also to gages which may be specified in individual cases. The castings shall be made in a workmanlike manner. A variation of $\frac{1}{8}$ in. per ft. will be permitted.

Finish. 9. The castings shall be free from injurious defects.

IV. MARKING.

Marking. 10. The manufacturer's identification mark and the pattern numbers assigned by the purchaser shall be cast on all castings of sufficient size, in such positions that they will not interfere with the service of the castings.

V. INSPECTION AND REJECTION.

Inspection.

11. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The manufacturer shall be required to keep a record of each melt from which castings are produced, showing tensile strength and elongation of test specimens cast from such melts. These records shall be available and shown to the inspector whenever required.

Rejection.

12. Castings which show injurious defects subsequent to their acceptance at the manufacturer's works may be rejected, and, if rejected, shall be replaced by the manufacturer free of cost to the purchaser.

STANDARD SPECIFICATIONS
FOR
GRAY-IRON CASTINGS.

Serial Designation: A 48 – 18.

These specifications are issued under the fixed designation A 48; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1905; REVISED, 1918.

Material Covered. 1. These specifications cover three classes of gray-iron castings, as follows:

(*a*) *Light Castings*, those having any section less than ½ in. in thickness;

(*b*) *Heavy Castings*, those in which no section is less than 2 in. in thickness;

(*c*) *Medium Castings*, those not included in either of the above two classes.

Basis of Purchase. 2. The tension test will be made only when specified by the purchaser and at his expense.[1]

I. MANUFACTURE.

Process. 3. The castings shall be made by the cupola process, unless furnace iron is specified.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. (*a*) Drillings taken from the fractured end of the transverse test bars shall conform to the following requirements as to sulfur:

Light castings	not over	0.10	per cent.
Medium castings	" "	0.10	"
Heavy castings	" "	0.12	"

(*b*) One sulfur determination shall be made for each mold of test bars cast, in accordance with the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (Serial

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[1] It is recommended by Committee A-3 on Cast Iron that the tension test shall not be made, for the reason that cast iron is almost devoid of elasticity, and hence any deviation from an absolutely straight pull in commercial testing machines yields defective results.

Designation: A 64) of the American Society for Testing Materials. In case of dispute, the standards of the U. S. Bureau of Standards shall be used for comparison.

III. PHYSICAL PROPERTIES AND TESTS.

Transverse Tests.

5. (*a*) The transverse test specimens (arbitration test bars) specified in Section 7 (*a*), when placed horizontally upon supports 12 in. apart and tested under a centrally applied load, shall conform to the following minimum requirements, interpreted in accordance with Section 9:

	Class of Casting.		
	Light.	Medium.	Heavy.
Load at center, lb	2 500	2 900	3 300
Deflection at center, in	0.10	0.10	0.10

(*b*) The rate of application of the load shall be such that a central deflection of 0.10 in. is produced in from 20 to 40 seconds.

Tension Tests.

6. When tension tests are specified, the tension test specimen shall conform to the following minimum requirements as to tensile strength:

Light castings	18 000 lb. per sq. in.
Medium castings	21 000 " "
Heavy castings	24 000 " "

Test Specimens

7. (*a*) *Arbitration Test Bar.*—The form and dimensions of the mold for the arbitration test bar shall be in accordance with Fig. 1. The bottom of the bar shall be $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask shall be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried, and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

(*b*) *Tension Test Specimen.*—When tension tests are specified, the tension test specimen shall be turned from any of the broken pieces of the transverse test specimens, and shall conform to the dimensions shown in Fig. 2.

Number of Tests.

8. (*a*) Two sets of two arbitration test bars each shall be cast from each melt, one set from the first and the other set from the last iron going into the castings. Where the melt

exceeds 20 tons, an additional set of two bars shall be cast for each additional 20 tons or fraction thereof. In case of a change of mixture during the melt, one set of two bars shall also be cast for every mixture other than the regular one. Each set of two bars shall be cast in a single mold.

(*b*) All arbitration test bars cast shall be tested as specified in Section 5 (*a*).

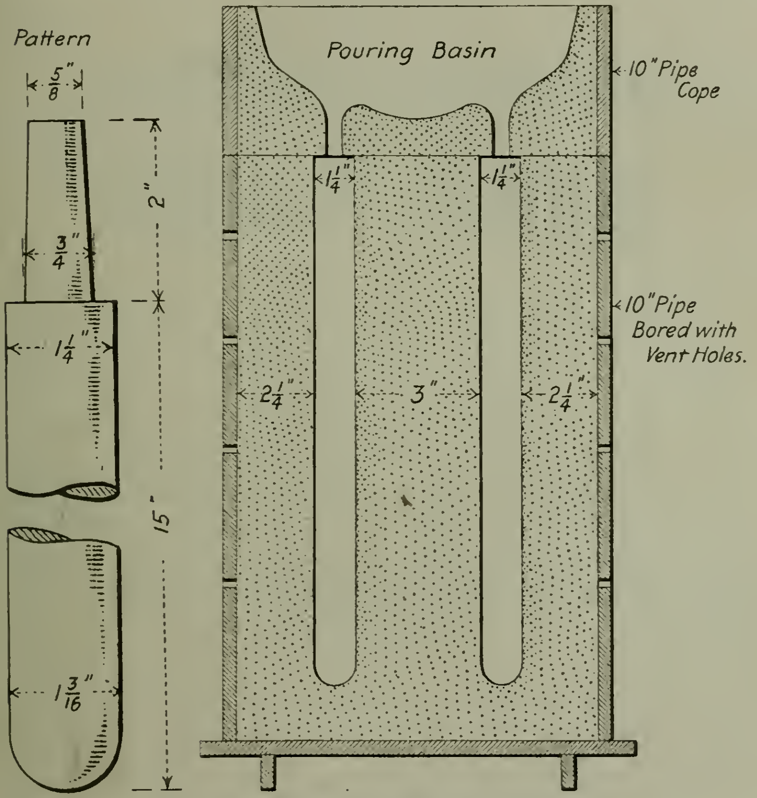

FIG. 1.—Mold for Arbitration Test Bar.

9. One arbitration test bar of each set cast shall conform to the requirements specified in Section 5 (*a*); otherwise the castings represented by such bars shall be rejected. **Requirements.**

IV. WORKMANSHIP AND FINISH.

10. The castings shall be true to pattern, and free from cracks, flaws and excessive shrinkage. In other respects they **Finish.**

shall conform to whatever points may be specially agreed upon between the manufacturer and the purchaser.

V. INSPECTION.

Inspection. 11. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

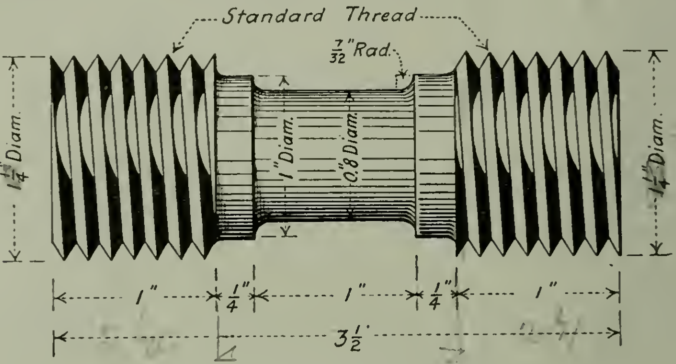

FIG. 2.—Tension Test Specimen.

STANDARD METHODS
OF
SAMPLING AND CHEMICAL ANALYSIS OF PIG AND CAST IRON.

Serial Designation: A 64 – 16.

These methods are issued under the fixed designation A 64; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1916.

SAMPLING.

Pig Iron.—One pig shall be selected at random from each four tons of iron and ten such pigs (representing 40 tons of iron) shall constitute a unit for sampling. The surface of each pig shall be cleansed with a stiff wire brush or in any manner that will remove all loose sand without introducing deleterious matter.

The skin, down to clean metal, shall then be removed with an emery wheel at the center of the upper face of each pig and the surface carefully brushed off.

Drillings shall be taken with a $\frac{1}{4}$-in. twist drill, from top to bottom of each pig, starting from the center of the cleared space and stopping when the point of the drill appears below. One hole only shall be bored in each pig.

Suitable precautions shall be taken to prevent the escape of fine particles during the drilling. To this end a disk of clean sheet metal shall be clamped upon the pig after the skin has been removed. This disk shall have a hole in its center just large enough to receive the drill. Most of the drillings will then accumulate on top of the disk and can be brushed off after the drill is withdrawn. The pig shall then be turned bottom side up over any suitable receptacle for collecting what may have remained in the drill hole.

Castings.—In accordance with the Standard Specifications for Gray-Iron Castings (Serial Designation: A 48) of the American Society for Testing Materials, three test bars, 1.2 in. in diameter, shall be cast in sand from each heat at the beginning and again at the end of the pouring.

One bar from each set having been broken, one end of each next the fracture shall be thoroughly cleaned and the outer skin removed for a sufficient distance from the fracture and down to clean metal. Chips shall then be taken by means of a lathe or milling machine across the whole face of the bar and until not less than 100 g. weight has been collected. The same amount shall be taken from each bar. The bar shall be so clamped as to permit the attachment or use of any suitable device for collecting every part of the sample and the machine shall be run slowly enough to reduce to a minimum the danger of loss of fine particles.

Subsequent Treatment of Sample from both Pig and Castings.—In the determination of total and graphitic carbon, and in the case of check analyses on the other constituents, the following precautions shall be taken: The entire unit shall be weighed and then sifted on tight-fitting sieves (with cover) having 80 (and if need be 120) meshes to the linear inch (approximately 900 and 2500 per square centimeter). The finer sieve need be used only in case the particles passing the coarser sieve are not sufficiently uniform in size and shape to meet the requirements of the treatment that follows.

The two (or three) portions so obtained shall be separately weighed. Each one shall then be thoroughly mixed without any loss of material and divided by weight into two (or three) exactly equal portions, each of which shall be placed in a clean, glass-stoppered bottle or other receptacle of suitable material and appropriately labeled. Of the three sets of the subdivided samples, one shall be retained by the works, one sent to the purchaser's chemist and the third reserved.

Before weighing out for analysis, the contents of each bottle shall be thoroughly mixed and each portion used for analysis shall be made up of the two (or three) partial samples in the same proportion which they bear to the gross sample. Thus, if the gross sample, weighing, say, 500 g., has been separated into portions weighing 400, 80, and 20 g., the amounts of each that must be weighed to yield a 2-g. portion for analysis are 1.6 g., 0.32 g., and 0.08 g., respectively.

METHODS OF CHEMICAL ANALYSIS.

DETERMINATION OF SILICON
BY THE
NITRO-SULFURIC (DROWN) METHOD.

SOLUTIONS REQUIRED.

Nitro-Sulfuric Acid.—Mix 1000 cc. of sulfuric acid, sp. gr. 1.84, 1500 cc. of nitric acid, sp. gr. 1.42, and 5500 cc. of distilled water.

Dilute Hydrochloric Acid.—Mix 100 cc. of hydrochloric acid, sp. gr. 1.20, and 900 cc. of distilled water.

METHOD.

Add cautiously 30 cc. of the nitro-sulfuric acid to 1 g. of iron in a platinum or porcelain dish of 300-cc. capacity, cover with a clock glass, heat until the metal is dissolved, and evaporate slowly until copious fumes of sulfuric acid are evolved. Cool, add 125 cc. of distilled water, heat with frequent stirring until all salts are dissolved, add 5 cc. of hydrochloric acid, sp. gr. 1.20, heat for 2 minutes, and filter on a 9-cm. paper. Wash the precipitate several times with hot water, then with hot hydrochloric acid and hot water alternately to complete the removal of iron salts, and finally with hot water until free from acid. Transfer the filter to a platinum crucible, burn off the paper carefully with the crucible covered, finally igniting over a blast lamp or in a muffle furnace at 1000° C. for at least 20 minutes; cool in a desiccator and weigh. Add sufficient sulfuric acid, sp. gr. 1.84, to moisten the silica and then a small amount of hydrofluoric acid. Evaporate to dryness, ignite and weigh. The difference in weights represents silica from which the percentage of silicon may be calculated.

Run a blank determination on all reagents.

DETERMINATION OF SILICON
BY THE
HYDROCHLORIC-ACID METHOD.

SOLUTIONS REQUIRED.

Hydrochloric Acid.—Mix equal volumes of hydrochloric acid, sp. gr. 1.20, and distilled water.

METHOD.

Place 1 or 2 g. of the metal in a casserole or 400-cc. beaker and add 30 to 40 cc. of the hydrochloric acid. When action has ceased, evaporate to dryness and bake in an air bath or on a hot plate until all acid is removed. Cool, add 15 cc. of concentrated hydrochloric acid and heat until all iron salts are in solution. Dilute with four or five times the volume of water, filter, wash, ignite and treat the precipitate as described under the Nitro-Sulfuric Method.

DETERMINATION OF SULFUR.

SOLUTIONS REQUIRED.

Barium Chloride.—Dissolve 100 g. of barium chloride ($BaCl_2 \cdot 2H_2O$) in 1000 cc. of distilled water.

METHOD.

Dissolve 5 g. of iron in a 400-cc. beaker, using a mixture of 40 cc. of nitric acid, sp. gr. 1.42, and 5 cc. of hydrochloric acid, sp. gr. 1.20. Add 0.5 g. of sodium carbonate, evaporate the solution to dryness and bake the residue on the hot plate until fumes are no longer given off. Treat the residue in 30 cc. of strong hydrochloric acid, dilute and filter. (See subsequent paragraph in this section for treatment of this residue for extraction of its possible sulfur content.) Cool the filtrate and add ammonia until a permanent cloudiness appears, then add 5 cc. of strong hydrochloric acid so as to obtain a perfectly clear liquid. Precipitate the sulfur in the cold filtrate (about 100 cc.) with 10 cc. of the barium-chloride solution. After 24 to 48 hours collect the precipitate on a filter paper, wash first with hot water (containing 10 cc. of concentrated hydrochloric acid and 1 g. of barium chloride to the liter) until free from iron, and then with hot water till free from chloride; or, first with cold water, then with 25 cc. of water containing 2 cc. of concentrated hydrochloric acid to the liter. Keep the washings separate from the main filtrate and evaporate them to recover any dissolved barium sulfate.

Place the insoluble residue, containing silica, graphite, etc., in a platinum crucible, cover with sodium carbonate (free from sulfur) and char the paper (use an alcohol lamp for this and subsequent heating operations) without allowing the carbonate to melt; the crucible should be covered during this operation. Then thoroughly mix in 0.2 g. of sodium nitrate and fuse the mass with the cover removed. Dissolve the contents of the crucible in water, filter and evaporate the filtrate with hydrochloric acid in excess, using a porcelain container; repeat the evaporation with water and hydrochloric acid to insure removal of nitrates. Extract the residue with a few drops of hydrochloric acid and water, filter off the insoluble matter and add barium chloride to the filtrate. Add the barium sulfate obtained to the main portion.

Run a blank with all reagents.

DETERMINATION OF PHOSPHORUS.

SOLUTIONS REQUIRED.

Nitric Acid for Dissolving.—Mix 1000 cc. of nitric acid, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of nitric acid, sp. gr. 1.42, and 1000 cc. of distilled water.

Ammonium-Molybdate Solution for Precipitating.

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of ammonium hydroxide, sp. gr., 0.90, filter and add 60 cc. of nitric acid, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of nitric acid, sp. gr., 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water; agitate thoroughly, let stand at least 24 hours and filter before using.

Ammonium-Molybdate Solution for Washing.—Mix equal volumes of the above compounded molybdate solution and of water.

Potassium-Nitrate Solution.—Dissolve 10 g. of potassium-nitrate in 1000 cc. of distilled water.

Phenolphthalein Solution.—Dissolve 0.2 g. of phenolphthalein in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium-Hydroxide Solution.—To 100 g. of pure sodium hydroxide add an amount of distilled water just insufficient to completely dissolve it. Pour into a tall cylinder, close the cylinder and allow the insoluble matter to settle. Dilute in the proportion of 30 cc. to 2000 cc. of distilled water.

Standard Nitric Acid.—Measure 2000 cc. of distilled water into a glass-stoppered bottle, add 20 cc. of nitric acid, sp. gr. 1.42, and mix thoroughly. Measure accurately 10 cc. of the "standard sodium-hydroxide solution." Place this in a small flask, add 40 cc. of distilled water and 3 drops of "phenolphthalein solution." Drop "standard nitric acid" from a carefully calibrated burette into the flask until the pink color just disappears. If the solutions are not of the same strength, dilute the stronger with water until they agree.

The solutions being of equal strength, standardize them as follows: Titrate the ammonium phosphomolybdate from an iron in which the phosphorus has been accurately determined, and divide the percentage of phosphorus by the number of cubic centimeters of the "standard sodium-hydroxide solution" required to neutralize it. The result is the value of the "standard sodium-hydroxide solution." The solution should preferably be of such strength that 1 cc. = 0.0002 g. of phosphorus. Protect the solution from carbon dioxide by a soda-lime tube.

Magnesia Mixture.—Dissolve 110 g. of crystallized magnesium chloride ($MgCl_2 \cdot 6H_2O$) or 50 g. of the anhydrous salt in distilled water, and filter. Dissolve 28 g. of ammonium chloride in distilled water, add a little bromine water and a slight excess of ammonia and filter. Add this solution to the solution of magnesium chloride, add enough ammonia to make the solution smell decidedly of ammonia, dilute to about 2 liters, transfer to a bottle, shake vigorously from time to time, allow it to stand for several days, and filter into a small bottle as required for use. Ten cubic centimeters of this solution will precipitate about 0.15 g. of P_2O_5.

Ammonia Wash Water, Approximately 10 per cent.—Mix 1000 cc. of ammonia water, sp. gr. 0.90, and 2000 cc. of distilled water in which has been dissolved 25 g. of ammonium nitrate.

METHODS.

A. MOLYBDATE METHOD FOR NON-TITANIFEROUS IRONS.

Procedure for Obtaining Phosphomolybdate.—In a 400 cc. beaker dissolve 1 g. of metal (2 g. for irons low in phosphorus), using 25 (or 50) cc. of "nitric acid for dissolving." Evaporate to dryness and heat on the hot plate or in the air bath at approximately 200° C. for about an hour. Allow the beaker to cool, dissolve the residue in 15 cc. of concentrated hydrochloric acid and evaporate to dryness to render the silica insoluble. Redissolve in 15 cc. of concentrated hydrochloric acid, dilute with water, filter off insoluble and wash. (Burn off the filter paper and graphite; expel silica with a few drops of hydrofluoric acid and a drop or two of sulfuric acid, taking care not to drive off all of the last-named acid. Take up the residue with concentrated hydrochloric acid, dilute, and filter if need be into the main solution). Evaporate to a small volume until salts just begin to separate. Add 10 cc. of concentrated nitric acid and evaporate until salts again begin to separate; add 15 cc. more of concentrated nitric acid and evaporate to a small volume. The solution being in an Erlenmeyer flask and the initial volume not over 25 cc. and its temperature that of the room, add 25 to 100 cc. of the molybdate reagent, according to the phosphorus content of the iron, shake for 4 or 5 minutes and let stand for 30 minutes to 3 or 4 hours at room temperature.

Then (*a*): Filter on a Gooch crucible, wash with the solution of "ammonium-molybdate solution for washing" and then with water containing 1 per cent of nitric acid, dry at 120° C. and weigh as ammonium phosphomolybdate containing 1.63 per cent of phosphorus.

Or, (*b*): Filter on a 9-cm. paper and wash, first with the "nitric acid for washing," and then with "potassium-nitrate solution," until the washings are no longer acid. Place filter and precipitate in the precipitating vessel and run in from a pipette 10 cc. of the "standard sodium-hydroxide solution." If, after agitation, this is insufficient to dissolve the precipitate, add 10 cc. more, and if necessary continue the additions until the precipitate is dissolved. Dilute to 50 cc., add 3 drops of "phenolphthalein solution," and add from a burette "standard nitric acid" until the pink color disappears; subtract the number of cubic centimeters of "standard nitric acid" used from the number of cubic centimeters of "standard sodium-hydroxide solution" taken to dissolve the precipitate, and the remainder will be the number of cubic centimeters of the "standard sodium-hydroxide solution" required to neutralize the ammonium phosphomolybdate. From this calculate the amount of phosphorus.

Or, (*c*): Filter on a small filter and wash with the "ammonium-molybdate solution for washing" until a drop of the filtrate gives no reaction for iron with potassium ferrocyanide. Dissolve the precipitate in 2 or 3 cc. of strong ammonia and filter through the paper that held the precipitate into a small beaker of about 100-cc. capacity, washing with ammoniacal water. With large precipitates more ammonia may be needed, but always the amounts of ammonia and wash water used should be as small as is consistent with perfect solution of the precipitate and thorough washing. When the precipitate is small the filtrate and washings should amount to about 25 cc. Neutralize the solution with strong hydrochloric acid; if the yellow precipitate forms, add ammonia until it redissolves.[1]

To the cold alkaline liquid add very slowly 10 cc. of "magnesia mixture," stirring constantly, add a little more ammonia and again stir vigorously. It is well to stand the beaker in cold water and stir the solution several times after the precipitate has begun to form. After 4 hours, filter on a small filter and wash with the "ammonia wash water." Dry, ignite in a crucible very carefully to burn off the carbonaceous matter, and finally heat for 10 minutes over the blast lamp. (The heat should not be so high as to cause partial fusion of the pyrophosphate.) Fill the crucible half full of hot water, add from 5 to 20 drops of hydrochloric acid, and heat for a few minutes to dissolve the magnesium pyrophosphate. If a residue remains, filter, wash, ignite in the crucible used for the pyrophosphate, weigh it, and deduct its weight from that of the unpurified salt. Calculate the phosphorus on the basis of 27.84 per cent in $Mg_2P_2O_7$.

B. Molybdate Method for Irons containing Titanium.

Proceed as under method A until the solution resulting from treatment of the insoluble residue has been combined with the main solution. Then proceed according to Blair[2] up to a certain point, as follows:

Heat the solution nearly to boiling, remove from the flame and add gradually from a small beaker a mixture of 2 cc. of acid ammonium sulfite[3] and 10 cc. of ammonia, stirring constantly. The precipitate, which forms at first, redissolves, and when all but a little of the reagent has been added, replace the beaker over the flame. If, at any time while adding the sulfite solution, the precipitate formed will not redissolve, even after vigorous stirring, add a few drops of hydrochloric acid, and when the solution clears, continue the addition, very slowly, of the acid ammonium sulfite. After replacing the beaker over the flame, add to the solution (which should smell quite strongly of sulfurous anhydride) ammonia, drop by drop, until the solution is quite decolorized, and finally until a slight greenish precipitate remains undissolved even after vigorous stirring. Now add the remainder of the sulfite solution, which should throw down a white precipitate, which usually redissolves, leaving the solution quite clear and almost perfectly decolorized. Should any precipitate remain undissolved, however, add hydrochloric acid, drop by drop, until the solution clears, when it should smell perceptibly of sulfurous anhydride. If the reagents are used exactly in the proportions indicated, the reactions will take place as described, and the operations will be readily and quickly carried out. If the solution of acid ammonium sulfite is weaker than it should be, of course the ferric chloride will not be reduced, and the solution, at the end of the operation described above, will not be decolorized and will not smell of sulfurous anhydride. In this case add more acid ammonium sulfite (without the addition of ammonia) until the solution smells strongly of sulfurous anhydride, then add ammonia until the slight permanent precipitate appears, and redissolve it in as few drops of hydrochloric acid as possible. The solution being now very nearly neutral, the iron in the ferrous condition, and an excess of sulfurous acid present, add to the solution 5 cc. of hydrochloric acid to make it decidedly acid and to insure the complete decomposition of any excess of the acid ammonium sulfite that may be present. Boil the solution while a stream of carbon dioxide passes through it, until every trace of sulfurous anhydride is expelled[1]. Add a few drops of bromine water or of a solution of ferric chloride, and cool the solution by placing the beaker in cold water. To the cold solution add ammonia from a small beaker very slowly, and finally, drop by drop, with constant stirring. The green precipitate of ferrous hydroxide which forms at first is dissolved by stirring, leaving the solution perfectly clear, but subsequently, although the green precipitate dissolves, a whitish one remains, and the next drop of ammonia increases the whitish precipitate or gives it a reddish tint, and finally the greenish precipitate remains undissolved even after vigorous stirring, and another drop of ammonia makes the whole precipitate appear green. If before this occurs the precipitate does not appear decidedly red in color, dissolve the green precipitate, by a drop or two of hydrochloric acid, and add a little bromine water or ferric-chloride solution (1 or 2 cc.), then add ammonia as before, and repeat this until the reddish precipitate is obtained, and then the green coloration as described above. Dissolve the green precipitate in a very few drops of acetic acid (sp. gr. 1.04), when the precipitate remaining will be quite red in color, then add about 1 cc. of acetic acid, and dilute the solution with boiling water, so that the beaker may be about four-fifths full. Heat to boiling, and when the solution has boiled one minute, lower the flame, filter as rapidly as possible through a 14-cm. filter, and wash once with hot water. The filtrate should run through clear, but in a few minutes it will appear cloudy by the precipitation of ferric hydroxide. The points to be observed are the red color of the precipitate and the clearness of the solution when it first runs through.

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[1] If a flocculent white precipitate now shows, filter it off, dry and ignite it in a platinum crucible, fuse the residue with a very little sodium carbonate, extract the melt with hot water, filter, acidify the filtrate with nitric acid, add some ammonium nitrate and molybdate reagent and if phosphorus is indicated by the formation of a yellow precipitate, filter, wash and dissolve this in ammonia and add to the main solution.

[2] "The Chemical Analysis of Iron," 7th Ed., p. 81.

[3] Made by saturating strong ammonia water with sulfur-dioxide gas. Eighteen cubic centimeters of such a solution will deoxidize a solution of 10 g. of iron.

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[1] If arsenic is present pass a current of hydrogen-sulfide gas through the solution for 15 minutes, filter, and expel excess of the precipitant by a current of carbon dioxide.

Dry the filter and precipitate without scorching the paper. Remove with filter paper any precipitate adhering to the beaker and dry the paper. Transfer the main portion of the precipitate (all that can be removed) to a small porcelain mortar. Burn carefully the filter and the wipings of the beaker and transfer the ash to the mortar. Grind the contents of the mortar with 3 g. of sodium carbonate and a little nitrate and transfer the mixture to a platinum crucible, cleaning pestle and mortar with a little sodium carbonate. Fuse the whole for half an hour or more, cool, dissolve the fused mass in hot water, filter,[1] and wash with hot water.

Acidify the alkaline solution with nitric acid, evaporate in a small casserole nearly to dryness, transfer to a small Erlenmeyer flask, so that the final volume shall not exceed 25 cc., add at room temperature 25 to 100 cc. of the molybdate reagent and shake for 4 or 5 minutes. Let stand for 30 minutes to 3 or 4 hours. From this point the procedure is exactly as described for non-titaniferous irons under method A.

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[1] The residue on the filter contains the whole of the titanium.

DETERMINATION OF MANGANESE
BY THE
BISMUTHATE METHOD.

SOLUTIONS REQUIRED.

Nitric Acid for Solution.—Mix 500 cc. of nitric acid, sp. gr. 1.42, and 1500 cc. of distilled water.

Nitric Acid for Washing.—Mix 30 cc. of nitric acid, sp. gr. 1.42, and 970 cc. of distilled water.

Stock Sodium Arsenite.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of sodium carbonate and 150 cc. of distilled water. Heat the flask and contents in a water bath until the oxide is dissolved, cool the solution and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite.—Dilute 300 cc. of "stock sodium arsenite" solution to 1000 cc. with distilled water and titrate against potassium-permanganate solution (about N/10), which has been standardized by using Bureau of Standards Sodium Oxalate.[1]

Adjust the solution so that 1 cc. is equivalent to 0.10 per cent of manganese, when a 1-g. sample is taken.

The factor $Na_2C_2O_4 \longrightarrow Mn = 0.16397$ (using the 1913 atomic weights).

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 1 g. of iron in 50 cc. of the "nitric acid for solution" and boil to expel the oxides of nitrogen, cool, filter,[2] add about 0.5 g. of sodium bismuthate, and heat for a few minutes or until the pink color has disappeared, with or without precipitation of manganese dioxide. Add small portions of ferrous sulfate (or any suitable reducing agent) in sufficient quantity to clear the solution and boil to expel the oxides of nitrogen. Cool to about 15° C., add an excess of sodium bismuthate and agitate for a few minutes. Add 50 cc. of the "nitric acid for washing" and filter through an alundum filter or asbestos pad,[3] washing with the same nitric acid. Titrate immediately with "standard sodium arsenite" solution to the disappearance of the pink color, each cubic centimeter required representing 0.10 per cent manganese.

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[1] *Circular No. 40*, Bureau of Standards, Oct. 1, 1912.

[2] The insoluble residue should be examined for manganese.

[3] In making the asbestos pad it is advisable to have a thin bed and as much surface as possible. This insures rapid filtration, and the filter may be used until it becomes clogged with bismuthate. The filtrate must be perfectly clear, since the least particle of bismuthate carried through the filter will vitiate the results.

DETERMINATION OF MANGANESE
BY THE
FORD-WILLIAMS METHOD.

SOLUTIONS REQUIRED.

Nitric Acid for Solution.—Mix equal volumes of nitric acid, sp. gr. 1.42, and distilled water.

Standard Ferrous-Sulfate Solution.—Dissolve 10 g. of pure crystallized $Fe_2SO_4 \cdot 7H_2O$ in 900 cc. of distilled water and 100 cc. of sulfuric acid, sp. gr. 1.84.

Standard Permanganate Solution, about N/10.—Dissolve 3.735 g. of potassium permanganate in 1000 cc. of distilled water. After aging, standardize this solution by means of sodium oxalate of ascertained purity (Sörensen's as furnished by the Bureau of Standards for a fee of $2.00 for 120 g. or $3.00 for 200 g.).

METHOD.

Dissolve 3 g. of iron in 40 cc. of "nitric acid for solution," dilute, filter,[1] and evaporate almost to a syrupy consistency. Add 40 cc. of nitric acid, sp. gr. 1.42, and 3 g. of potassium chlorate. Boil the solution for 15 minutes. Remove from the source of heat and add 15 cc. of nitric acid, sp. gr. 1.42, and 3 g. of potassium chlorate. Boil again until yellow fumes cease to come off. Cool quickly and filter on an asbestos pad in a carbon funnel. Wash with cold nitric acid, sp. gr. 1.42 (free from oxides of nitrogen[2] until the iron is removed and then with water until the nitric acid is removed. Transfer the filter to the beaker in which precipitation was made, add a measured amount of the "standard ferrous-sulfate solution," so that there shall be an excess, and titrate the excess with the "standard permanganate solution."

In another operation titrate the same amount of "standard ferrous-sulfate solution" directly against the permanganate. The difference between the two amounts of permanganate used gives the measure of the manganese present in the iron. The comparison of the ferrous sulfate and permanganate solutions should be made each day they are used.

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[1] The insoluble residue should be examined for manganese.

[2] It is very important to use nitric acid free from oxides of nitrogen, since these dissolve the precipitated manganese dioxide.

DETERMINATION OF CARBON
BY THE
DIRECT-COMBUSTION METHOD.

The method of direct combustion of the metal in oxygen is recommended, the carbon dioxide obtained being absorbed in barium-hydroxide solution, the precipitated barium carbonate filtered off, washed, dissolved in a measured excess of hydrochloric acid and the excess titrated against standard alkali.

The use of potassium-hydroxide solution or soda lime for the absorption of carbon dioxide, with suitable purifying train between absorption tube and furnace, is recognized as being capable of very satisfactory refinement and as possessing merit where the time element is of prime significance.

Owing to the diversity of apparatus by which correct results may be obtained in the determination of carbon, the recommendations are intended more to indicate what is acceptable than to prescribe definitely what shall be used.

APPARATUS.

Purifying Train.—The method employed eliminates the necessity of a purifying train following the furnace, inasmuch as no precautions are necessary to prevent access of water vapor, or sulfur trioxide—the impurities usually guarded against—from the absorbing apparatus. All that is needed is a calcium-chloride tower filled with stick sodium hydroxide placed before the furnace, or between the furnace and catalyzer, if, as recommended, the latter is used for the purpose of oxidizing organic matter in the oxygen.

Material for Lining Boats.—Alundum, "RR Alundum, alkali-free, specially prepared for carbon determination," as supplied by dealers is suitable, and is recommended. The 90-mesh or finer grades are used. Chromite, properly sized and freed from materials causing a blank, may also be employed. No substance containing alkali or alkaline earth metals, or carbon as carbonates or in other form, should be used as a lining material. Quartz sand, owing to its liability to fuse or to slag with the oxides of iron, causing bubbles of gas to be enclosed, is objectionable. Aluminum oxide, made by calcining alum or otherwise, often contains sulfate not easily destroyed, or may contain objectionable substances of an alkaline nature.

Catalyzers.—Suitable catalyzers are copper oxide, platinized quartz or asbestos, or platinum gauze. One of these should be used in the forward part of the combustion apparatus, as well as in the purifying train preceding the combustion tube (see above). Platinized materials sometimes give off volatile substances on heating, and whatever material is used should not be subject to this defect.

Combustion Apparatus.—Any apparatus heated by gas or electricity which will bring the sample to a temperature of 950 to 1100° C. may be used. Combustion tubes may be porcelain, glazed on one or both sides, quartz or platinum. Quartz is liable to devitrification when used continuously at temperatures above 1000° C., and may then become porous. Combustion crucibles of platinum may be heated by blast or by Meker burners.

Boats or Other Containers of Samples being Burned.—These may be of porcelain, quartz, alundum, clay, platinum, or nickel, and should always receive a lining of granular alundum.

Purifying Train before Combustion Apparatus.—This consists of a tower filled with stick sodium hydroxide, preceded by a catalyzer.

The Train after the Combustion Apparatus.—This consists merely of the Meyer tube for absorption of the carbon dioxide, protected by a soda-lime tube at the far end. Meyer tubes with 7 to 10 bulbs of 10 to 15-cc. capacity each, and large bulbs at the ends, having volumes equal to the combined capacity of the small bulbs, have been used and found satisfactory.

Filtering Apparatus.—In filtration for accurate work, care should be taken to protect the solution from access of extraneous carbon dioxide. This is accomplished in the apparatus shown in Fig. 1. For work requiring less accuracy, the barium carbonate may be filtered off on a filter made by fitting a carbon funnel with a perforated procelain disk and filtering by suction. The precipitate is then washed with distilled water from which the carbon dioxide has been removed by boiling.

REAGENTS.

Oxygen.—Oxygen of not less than 97-per-cent purity is recommended. Endeavor should be made to obtain oxygen which gives no blank, since the correction for or elimination of this is troublesome and uncertain. For the most accurate work the blank should be completely eliminated by the use of a catalyzer before the furnace, with a carbon-dioxide absorbent interposed between furnace and catalyzer.

Tenth-normal Hydrochloric Acid.—This may be standardized by any of the accepted methods, or as follows: Twenty cubic centimeters of the approximately N/10 acid is measured out with a pipette, and the silver chloride precipitated by an excess of silver-nitrate solution in a volume of 50 to 60 cc. After digesting at 70 to 80° C., until the supernatant liquid is clear, the chloride is filtered off on a tared Gooch filter and washed with water containing 2 cc. of nitric acid per 100 cc. of water, until freed from silver nitrate. After drying to constant weight at 130° C., the increase of weight over the original tare is noted, and from this weight, corresponding to the silver chloride, the strength of the hydrochloric acid is calculated, after which it is adjusted to the strength prescribed. The standardization should be based upon several concordant determinations, using varying amounts of acid.

$$1 \text{ cc. N/10 HCl} = 0.0006 \text{ g. carbon.}$$

Methyl Orange.—Dissolve 0.02 g. in 100 cc. of hot distilled water and filter.

Tenth-normal Sodium-Hydroxide Solution.—This is standardized against the hydrochloric acid. Methyl orange is used as the indicator. The sodium-hyroxide solution should be stored in a large bottle from which it may be driven out by air pressure, protecting against carbon dioxide by soda-lime tubes.

Barium-Hydroxide Solution.—A saturated solution is filtered and stored in a large reservoir from which it is delivered by air pressure, protecting from carbon dioxide by a soda-lime tube. Use enough of this solution to fill all the small bulbs of the Meyer tube when the latter is properly set up for absorption.

FACTORS INFLUENCING RAPID COMBUSTION.

Manner of Distributing Sample in Boat.—This is of considerable importance. With all samples. close packing in a small space is conducive to rapid combustion. In the case of samples which burn too vigorously, a satisfactory regulation may sometimes be attained by spreading the sample loosely over the lining in the boat.

Rate of Admitting Oxygen.—The rate at which oxygen is admitted is also a factor in the velocity of combustion; a moderate rate of burning is to be sought. This is desirable from the standpoint of the complete absorption of the carbon dioxide by the barium-hydroxide solution. The above-mentioned factors can be governed so as to burn successfully irons of a very wide range of compositions, in either fine or coarse particles.

METHOD.

After having properly set up and tested the apparatus, place 1 g. of iron in a moderately packed condition on the bed material and introduce the boat into the combustion apparatus, already heated to the proper temperature. After about a minute (to allow the sample and container to reach the temperature of the furnace), admit oxygen somewhat more rapidly than it is consumed, as shown by the rate of bubbling in the Meyer tube.[1] The sample burns completely in 1 or 2 minutes, and all that is now necessary is to sweep all the carbon dioxide into the absorption apparatus. This can be accomplished in 6 to 8 minutes by passing about 1 or 2 liters of oxygen. Detach the Meyer tube and filter and wash the barium carbonate, using the special filtering apparatus shown. After solution in a measured excess of hydrochloric acid (the Meyer tube being washed out with a portion of the acid, to remove adhering barium carbonate), titrate the excess of acid against alkali and from the data thus obtained calculate the percentage of carbon.

APPARATUS AND PROCEDURE FOR FILTRATION.

The apparatus is shown to approximately one-tenth size in Fig. 1, which is self-explanatory. The stop-cock is a three-way cock connected to the suction pipe. The rubber tubing connected to the Meyer tube should be of best grade black rubber and the lengths should be so chosen as to permit of easy manipulation of the tube.[2] The Meyer tube is connected or disconnected by the rubber stoppers which are left always attached to the rubber tubes. The carbon tube C is fitted with a perforated porcelain plate sliding easily.

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[1] As a precaution against error resulting from too rapid passage of the gases, it is well to attach a second barium-hydroxide tube to retain any carbon dioxide that may pass the first.

For the most accurate work the Meyer tubes should be washed with dilute acid before beginning work each day. After a determination is finished the tube should be completely filled two or three times with tap water, then rinsed with distilled water, in order to remove the carbon dioxide liberated when dissolving the carbonate from the previous determination.

The flask containing the carbonate should be thoroughly agitated after adding the acid, since the carbonate sometimes dissolves rather slowly if this is not done; this is particularly the case if it has packed much during filtration.

[2] It is well to wash out the rubber tubes connected to the Meyer tube with a little water each day before beginning work.

The funnel is prepared for filtration by making on the porcelain disk a felt of asbestos about $\frac{1}{16}$ to $\frac{1}{8}$ in. in thickness, using amphibole (not serpentine) asbestos which has been carefully digested with strong hydrochloric acid for several hours and washed with water until it gives no acid reaction. On top of the asbestos pad is placed a layer of similarly treated quartz mixed with asbestos, of the height shown. A mixture of quartz grains of various sizes (approximately 50 per cent passing a 20-mesh sieve and 50 per cent passing a 10-mesh and remaining on a 20-mesh sieve) is suitable. The mixture of quartz and asbestos may be obtained by filling the funnel from a beaker (directing against it a stream from a wash-bottle) while maintaining a gentle suction. In this way the asbestos is properly mixed with the quartz. A little experience and attention to these details will enable one to prepare the quartz-bed in a manner that will greatly expedite filtration.[1] The stopper is now inserted in the funnel, the Meyer tube connected as shown and the liquid and precipitate sucked into the funnel. Only a gentle suction should be used. When necessary P_3 is opened to admit air back of the column of liquid in the Meyer tube.

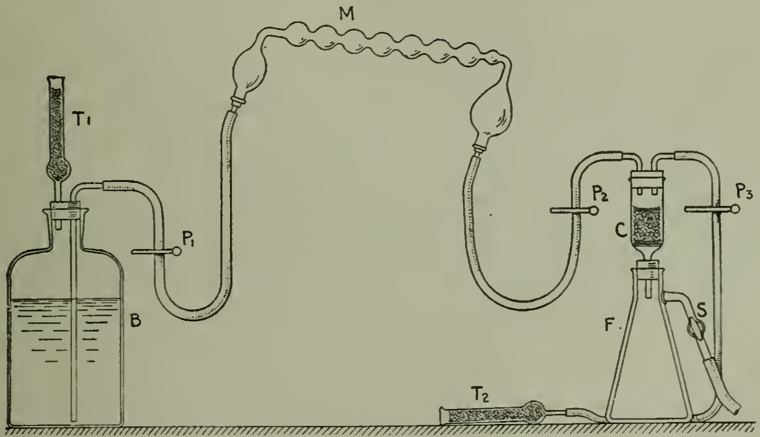

FIG. 1.—Apparatus for Filtering Barium Carbonate.

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[1] Glass wool should on no account be used as a substitute for the quartz, on account of the probability of errors arising from its attack by the alkali or acid.

When the contents of the Meyer tube have been transferred, the large bulb nearest B is half filled with water by opening P_1; the stop-cock S is operated during this and subsequent operations so as to maintain a gentle suction all the time. M is now manipulated so as to bring the wash water in contact with all parts of the interior, after which the water is sucked through C; P_2 is left open during this and subsequent washings.[1] After eight washings as directed, allowing the wash water to drain off thoroughly each time before adding more, M may be detached, the stopper removed from the funnel and the washing completed by filling C to the top with CO_2-free water, sucking off completely and repeating the operation once. With care the washing may be done with 150 cc. of water. Air is now admitted through the side opening of S, C is removed and the porcelain disk carrying the asbestos, quartz and barium carbonate is thrust, by means of a long glass rod, into a flask, removing any adhering particles from the sides of C, by a stream of water from a wash bottle. An excess of the standard acid is now added from a burette or pipette, using a portion to wash out M, and after the contents of the flask have been thoroughly agitated by shaking, the excess of acid is titrated against the standard alkali, using 3 drops of the methyl-orange indicator.

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[1] The operation of filtering can be carried out very rapidly after a little practice.

STANDARD SPECIFICATIONS

FOR

LAKE COPPER WIRE BARS, CAKES, SLABS, BILLETS, INGOTS, AND INGOT BARS.

Serial Designation: B 4 – 13.

These specifications are issued under the fixed designation B 4; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1913.

These specifications were approved June 15, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

Definition.

1. In order to be classed as Lake, copper must originate on the northern peninsula of Michigan, U. S. A.

Marks.

2. All wire bars, cakes, slabs, and billets shall be stamped with the maker's brand and furnace charge mark. Ingots and ingot bars shall have a brand stamped or cast in, but need have no furnace charge mark.

Lots.

3. The refiner shall arrange carloads or lots so that as far as possible each shall contain pieces from but one furnace charge, in order to facilitate testing by the user.

Resistivity.

4. (*a*) *Low Resistance Lake.*—Lake copper offered for electrical purposes, whether fire or electrolytically refined, shall be known as "Low Resistance Lake."

Low Resistance Lake wire bars shall have a resistivity not to exceed 0.15535 international ohms per meter-gram at 20° C. (annealed). All ingots and ingot bars shall have a resistivity not to exceed 0.15694 international ohms per meter-gram at 20° C. (annealed).

Cakes, slabs, and billets shall come under the ingot classification, except when specified for electrical use at time of purchase; in which case wire-bar classification shall apply.

(*b*) *High Resistance Lake.*—Lake copper having a resistivity greater than 0.15694 international ohms per meter-gram at 20° C. shall be known as "High Resistance Lake."

Metal Content. 5. (*a*) Low Resistance Lake copper shall have a purity of at least 99.880 per cent as determined by electrolytic assay, silver being counted as copper.

(*b*) High Resistance Lake copper shall have a purity of at least 99.880 per cent, copper, silver, and arsenic being counted together. The arsenic content of High Resistance Lake copper, when required for special purposes, shall be the subject of agreement at time of purchase.

Physical Standard. 6. Wire bars, cakes, slabs, and billets shall be substantially free from shrink holes, cold sets, pits, sloppy edges, concave tops and similar defects in set or casting. This clause shall not apply to ingots or ingot bars, in which case physical defects are of no consequence.

Weights of Individual Pieces. 7. Five per cent variation in weight or $\frac{1}{4}$ in. variation in any dimension from the refiner's published list or purchaser's specified size shall be considered good delivery; provided, however, that wire bars may vary in length 1 per cent from the listed or specified length, and cakes 3 per cent from the listed or specified size in any dimension greater than 8 in. The weight of ingot and ingot-bar copper shall not exceed that specified by more than 10 per cent, but otherwise its variation is not important.

Claims. 8. Claims shall be made in writing within thirty days of receipt of copper at the customer's mill, and the results of the customer's tests shall accompany such claims. The refiner shall be given one week from date of receipt of complaint to investigate his records, and shall then either agree to replace the defective copper or send a representative to the mill. No claims will be considered unless made as above stated, and if the copper in question, unused, cannot be shown to the refiner's representative.

Claims against quality will be considered as follows:

(*a*) Resistivity by furnace charges, ingot lots, or ingot-bar lots.

(*b*) Metal contents by furnace charges, ingot lots, or ingot-bar lots.

(*c*) Physical defects by individual pieces.

(*d*) Variation in weights or dimensions by individual pieces.

Investigation of Claims. 9. The refiner's representative shall inspect all pieces where physical defects or variation in weight or dimension are claimed. If agreement is not reached, the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

In a question of metal contents each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately ½ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. The resulting samples shall be cut up, mixed, and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire if necessary. Each party shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact, and whose determination shall be final.

In a question of resistivity each party shall select two samples, and in the presence of both parties these shall be rolled hot and drawn cold into wire of 0.080 in. diameter, approximately, which shall be annealed at approximately 500° C. Three samples shall be cut from each coil and the same procedure followed as described in the previous paragraph.

Settlement of Claims.

10. The expenses of the shipper's representative and of the umpire shall be paid by the loser, or divided in proportion to the concession made in case of compromise. In case of rejection being established, the damage shall be limited to payment of freight both ways by the refiner for substitution of an equivalent weight of copper meeting these specifications.

EXPLANATORY NOTE.

These specifications have been drawn to cover the peculiar trade situation which has classified the large production of copper from this geographical district as a product in a class by itself.

It is realized that a better classification from an academic point of view could be made by method of production or by chemical composition, but the trade does not yet seem ready for such a step.

STANDARD SPECIFICATIONS

FOR

ELECTROLYTIC COPPER WIRE BARS, CAKES, SLABS, BILLETS, INGOTS, AND INGOT BARS.

Serial Designation: B 5 – 13.

These specifications are issued under the fixed designation B 5; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1913.

These specifications were approved June 15, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

Marks. 1. All wire bars, cakes, slabs, and billets shall be stamped with the maker's brand and furnace charge mark. Ingots and ingot bars shall have a brand stamped or cast in, but need have no furnace charge mark.

Lots. 2. The refiner shall arrange carloads or lots so that as far as possible each shall contain pieces from but one furnace charge, in order to facilitate testing by the user.

Quality. 3. (*a*) *Metal Content.*—The copper in all shapes shall have a purity of at least 99.880 per cent, as determined by electrolytic assay, silver being counted as copper.

(*b*) *Resistivity.*—All wire bars shall have a resistivity not to exceed 0.15535 international ohms per meter-gram at 20° C. (annealed); all ingot and ingot bars shall have a resistivity not to exceed 0.15694 international ohms per meter-gram at 20° C. (annealed).

Cakes, slabs, and billets shall come under the ingot classification, except when specified for electrical use at time of purchase, in which case wire-bar classification shall apply.

Physical Standard. 4. Wire bars, cakes, slabs, and billets shall be substantially free from shrink holes. cold sets, pits, sloppy edges, concave tops, and similar defects in set or casting. This clause shall not apply to ingots or ingot bars, in which case physical defects are of no consequence.

Weights of Individual Pieces.

5. Five per cent variation in weight or $\frac{1}{4}$ in. variation in any dimension from the refiner's published list or purchaser's specified size shall be considered good delivery; provided, however, that wire bars may vary in length 1 per cent from the listed or specified length, and cakes 3 per cent from the listed or specified size in any dimension greater than 8 in. The weight of ingot and ingot-bar copper shall not exceed that specified by more than 10 per cent, but otherwise its variation is not important.

Claims.

6. Claims shall be made in writing within thirty days of receipt of copper at the customer's mill, and the results of the customer's tests shall accompany such claims. The refiner shall be given one week from date of receipt of complaint to investigate his records, and shall then either agree to replace the defective copper or send a representative to the mill. No claims shall be considered unless made as above stated, and if the copper in question, unused, cannot be shown to the refiner's representative.

Claims against quality will be considered as follows:

(*a*) Resistivity by furnace charges, ingot lots, or ingot-bar lots.

(*b*) Metal contents by furnace charges, ingot lots, or ingot-bar lots.

(*c*) Physical defects by individual pieces.

(*d*) Variation in weights or dimensions by individual pieces.

Investigation of Claims.

7. The refiner's representative shall inspect all pieces where physical defects or variation in weight or dimension are claimed. If agreement is not reached, the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

In a question of metal contents each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately $\frac{1}{2}$ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. The resulting samples shall be cut up, mixed, and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire if necessary. Each party shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact, and whose determination shall be final.

In a question of resistivity each party shall select two samples, and in the presence of both parties these shall be rolled hot and drawn cold into wire of 0.080 in. diameter, approximately, which shall be annealed at approximately 500° C. Three samples shall be cut from each coil and the same procedure followed as described in the previous paragraph.

Settlement of Claims.

8. The expenses of the shipper's representative and of the umpire shall be paid by the loser, or divided in proportion to the concession made in case of compromise. In case of rejection being established, the damage shall be limited to payment of freight both ways by the refiner for substitution of an equivalent weight of copper meeting these specifications.

STANDARD SPECIFICATIONS

FOR

SPELTER.

Serial Designation: B 6 – 18.

These specifications are issued under the fixed designation B 6; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1914, 1918.

Grades. 1. Under these specifications Virgin Spelter, that is, spelter made from ore or similar raw material by a process of reduction and distillation or by electrolysis and not produced from reworked metal, is considered in five grades, as follows:

1..................High Grade.
2..................Intermediate.
3..................Brass Special.
4..................Selected.
5..................Prime Western.

Marks. 2. A brand shall be cast in each slab by which the maker and grade can be identified.

Lots. 3. The maker shall use care to have each carload of as uniform quality as possible.

Composition. 4. *1. High Grade.*[1]—The spelter shall not contain over:

0.07 per cent lead.
0.03 " iron.
0.07 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 0.10 per cent.

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[1] For slush castings and certain zinc-aluminum alloys, a special grade of spelter may be required, as noted in "Spelter, Its Grades and Uses," published as Appendix I to the report of Committee B-2, *Proceedings*, Am. Soc. Test. Mats., Vol. XVI, Part I, p. 183 (1916).

2. Intermediate.—The spelter shall not contain over:

0.20 per cent lead.
0.03 " iron.
0.50 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 0.50 per cent.

3. Brass Special.—The spelter shall not contain over:

0.60 per cent lead.
0.03 " iron.
0.50 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 1.0 per cent.

4. Selected.—The spelter shall not contain over:

0.80 per cent lead.
0.04 " iron.
0.75 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 1.25 per cent.

5. Prime Western.—The spelter shall not contain over:

1.60 per cent lead.
0.08 " iron.

Physical. 5. The slabs shall be reasonably free from surface corrosion or adhering foreign matter.

Sampling.[1] 6. Take ten slabs at random from a carload and saw each slab completely across from the middle of one long side to the middle of the other and use the sawdust as the sample; or, drill three 9-mm. holes along one diagonal of each slab, boring completely through and taking care to make fine drillings; the holes should be drilled as nearly as possible at the middle and halfway between either end and the middle of such diagonals. Go over the drillings or sawings with a powerful magnet to take out any iron which may have come from the drill or saw, and mix the sample thoroughly. The drill or saw shall be thoroughly cleaned before use, and no lubricant shall be used in either drilling or sawing.

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[1] Section 6 on Sampling is based on the Report of the Sub-Committee on Methods of Analysis of Non-Ferrous Alloys of the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society, approved by the Supervisory Committee on Standard Methods of Analysis of that Society; *Journal of Industrial and Engineering Chemistry*, Vol. 7, 1915, p. 547.

Claims.

7. Claims to be considered shall be in writing within thirty days of receipt of material at customer's plant and the results of customer's test shall be given. The shipper shall be given one week from date of receipt of such claim to investigate his records and then shall either agree to satisfy the claim or send a representative to the plant.

(*a*) *Analysis by Car Lots.*—No claims shall be considered unless the minimum samples as specified for the grade in question can be shown to such representative.

(*b*) *Physical Defects of Individual Pieces.*—No claims shall be considered unless the spelter in question, unused, can be shown to such representative.

Plant Treatment.

8. Where the spelter satisfies the chemical and physical requirements of these specifications, it shall not be condemned for defects of alloys in which it is used or for defects in the coating of galvanized products.

Investigation of Claims.

9. The maker's representative shall inspect all pieces where physical defects are claimed. If agreement is not reached the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

On a question of metal contents a sample shall be drawn by representatives of both parties as described under "Sampling," Section 6. The properly mixed and quartered sample shall be separated into three parts, each of which shall be placed in a sealed package, one for each party and one for an umpire if necessary. Each part shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of quality, and whose determination shall be final.

Settlement of Claims.

10. The expenses of the seller's representative and of the umpire shall be paid by the loser or divided in proportion to concession made in case of compromise.

In case of rejection being established, damages shall be limited to the payment of freight both ways by the seller for substitution of an equivalent weight of spelter meeting these specifications.

STANDARD SPECIFICATIONS
FOR
LIGHT ALUMINUM CASTING ALLOYS.

Serial Designation: B 26 – 21.

These specifications are issued under the fixed designation B 26; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1918; Adopted in Amended Form, 1921.

Material Covered. 1. These specifications cover commercial light alloys of aluminum having a specific gravity of 3 and less.

I. MANUFACTURE.

Process. 2. The alloy may be made by any approved method.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The following alloys are described by these specifications; they shall conform to the following requirements as to chemical composition:

Alloy.	Copper, per cent.	Zinc, per cent.	Manganese, per cent.	Maximum Total Impurities, per cent.	Aluminum, per cent.
A	7 – 8.5	......	......	1.7	Remainder
B	8.5 – 11	......	......	1.7	Remainder
C	11 – 14	......	......	1.7	Remainder
D	2.5 – 3.0	12.5 – 14.5	......	1.7[a]	Remainder
E	2 – 2.5	......	0.75 – 1.25	1.0	Remainder

[a] Lead content shall not be greater than 0.1 per cent.

Sampling. 4. (*a*) The sample for chemical analysis may be taken either by sawing, drilling or milling the casting or tension test specimen and shall represent the average cross-section of the piece.

(*b*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawdust or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 5. The alloys shall conform to the following minimum requirements as to tensile properties:

Alloy.	Minimum Tensile Strength, lb. per sq. in.	Minimum Elongation in 2 in., per cent.
A	18 000	1
B	18 000	..
C	19 000	..
D	25 000	1
E	18 000	8

Test Specimens. 6. (*a*) Two test bars of the form and dimensions shown in Fig. 1 shall be an integral part of large castings, or cast separately in the case of small castings to represent a lot or melt, and shall be molded in a manner similar to the castings which they represent. If the castings are heat-treated, the test bars representing such castings shall be similarly heat-treated.

(*b*) The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars.

(*c*) Tension test specimens, turned from the test bar shown in Fig. 1, shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

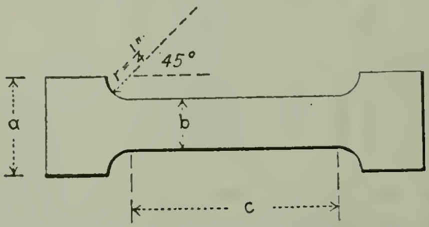
Number of Tests. 7. (*a*) Tests shall as far as possible be made by heats or melts, but unless otherwise agreed, two tension tests shall be made upon each unit lot of 500 lb. or single delivery of less than 500 lb.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

IV. INSPECTION AND REJECTION.

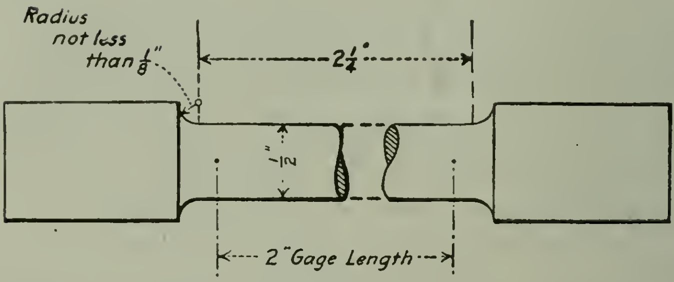
Inspection. 8. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.



a ---- 1 in.
b --- not greater than $\frac{5}{8}$ in., nor less than $\frac{1}{2}$ in.
c --- not less than $2\frac{1}{8}$ in.

FIG. 1.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

Rejection. 9. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected, shall be replaced by the manufacturer free of charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

EXPLANATORY NOTES.

The alloys described may be divided into two groups: those (A, B, C, D) having a relatively high hardness, as evidenced by the proportional limit, but little or no ductility; and E, which has a relatively low proportional limit, but a fair ductility. Thus the alloys A and D are quite suitable for general castings which, although highly stressed in service, will not likely be subjected to overstress. If a casting is likely to be subjected to a very rough treatment tending to overstress it, a more ductile alloy, E, is to be preferred.

Alloys B and C are suitable for high temperature and pressure service. Alloy B is recommended for pistons, alloy C for manifolds, carburetors, pumps, etc. Average values for other physical properties of these alloys are given in the following table:

PHYSICAL PROPERTIES OF ALUMINUM ALLOYS.

Alloy.	Density, g. per cc.	Shrinkage, in. per ft.	Temperature, Melting Range.		Proportional Limit, lb. per sq. in.
			Deg. Cent.	Deg. Fahr.	
A	2.89	0.156	637 - 640	1146 - 972	about 10 000
B	2.95	0.166	630 - 540	1133 - 972	....
C	3.00	0.166	623 - 540	1120 - 972	....
D	3.00	0.156	625 - 440	1124 - 792	....
E	2.79	0.156	649 - 529	1166 - 952	less than 2 000

Section 5.—The elongations obtained with Alloys B, C and D are generally less than 1 per cent and are too small to be satisfactorily measured.

Section 6.—Some latitude has been allowed in the diameter of the cast test bars; test bars cast to size are stronger than those which are machined, and the tensile properties specified can be obtained under usual conditions only with the cast-to-size bar.

It is strongly recommended that a self-centering form of tension test specimen holder be used. Most aluminum alloys (A, B, C, D) are brittle and give lower and less uniform test results when tested in ordinary wedge grips without centering.

STANDARD SPECIFICATIONS
FOR
HARD-DRAWN COPPER WIRE.

Serial Designation: B 1 – 15.

These specifications are issued under the fixed designation B 1; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1909; REVISED, 1911, 1913, 1915.

Material. 1. The material shall be copper of such quality and purity that, when drawn hard, it shall have the properties and characteristics herein required.

Shapes. 2. These specifications cover hard-drawn round wire, grooved trolley wire, and figure-eight trolley wire, as hereinafter described.

Finish. 3. (*a*) The wire, in all shapes, must be free from all imperfections not consistent with the best commercial practice.

(*b*) Necessary brazes in hard-drawn wire must be made in accordance with best commercial practice, and tests upon a section of wire containing a braze must show at least 95 per cent of the tensile strength of the unbrazed wire. Elongation tests are not to be made upon test sections including brazes.

Packages. 4. (*a*) Package sizes for round wire shall be agreed upon in the placing of individual orders; standard packages of grooved trolley wire shall be shipments upon reels holding about 2500 lb. each.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

Specific Gravity. 5. For the purpose of calculating weights, cross-sections, etc., the specific gravity of copper shall be taken as 8.89 at 20° C.

Inspection. 6. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

HARD-DRAWN ROUND WIRE.

Dimensions and Permissible Variations.

7. (*a*) Size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; that is, in mils.

(*b*) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.100 in. in diameter and larger, one per cent over or under;

For wire less than 0.100 in. in diameter, one mil over or under.

(*c*) Each coil is to be gaged at three places, one near each end, and one approximately at the middle; the coil may be rejected if, two points being within the accepted limits, the third point is off gage more than 2 per cent in the case of wire 0.064 in. in diameter and larger, or more than 3 per cent in the case of wire less than 0.064 in. in diameter.

Physical Test.

8. Wire shall be so drawn that its tensile strength and elongation shall be at least equal to the value stated in Table I. Tensile tests shall be made upon fair samples, and the elongation of wire larger in diameter that 0.204 in. shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The elongation of wire 0.204 in. in diameter and smaller shall be determined by measurements made between the jaws of the testing machine. The zero length shall be the distance between the jaws when a load equal to ten per cent of the required ultimate breaking strength shall have been applied, and the final length shall be the distance between the jaws at the time of rupture. The zero length shall be as near 60 in. as possible. The fracture shall be between the bench marks in the case of wire larger than 0.204 in. in diameter and between the jaws in the case of smaller wire, and not closer than 1 in. to either bench mark or jaw. If upon testing a sample from any coil of wire, the results are found to be below the values stated in the table, tests upon two additional samples shall be made, and the average of the three tests shall determine acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in Table I.

Electric Resistivity.

9. Electric resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.).

The wire shall not exceed the following limits:

For diameters 0.460 in. to 0.325 in., 900.77 lb. per mile-ohm at 20° C.;

For diameters 0.324 in. to 0.040 in., 910.15 lb. per mile-ohm at 20° C.

TABLE I.

Diameter, in.	Area, circular mils.	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent.
0.460	211 600	49 000	3.75
0.410	168 100	51 000	3.25
0.365	133 225	52 800	2.80
0.325	105 625	54 500	2.40
0.289	83 520	56 100	2.17
0.258	66 565	57 600	1.98
0.229	52 440	59 000	1.79
			in 60 in.
0.204	41 615	60 100	1.24
0.182	33 125	61 200	1.18
0.165	27 225	62 000	1.14
0.162	26 245	62 100	1.14
0.144	20 735	63 000	1.09
0.134	17 956	63 400	1.07
0.128	16 385	63 700	1.06
0.114	12 995	64 300	1.02
0.104	10 815	64 800	1.00
0.102	10 404	64 900	1.00
0.092	8 464	65 400	0.97
0.091	8 281	65 400	0.97
0.081	6 561	65 700	0.95
0.080	6 400	65 700	0.94
0.072	5 184	65 900	0.92
0.065	4 225	66 200	0.91
0.064	4 096	66 200	0.90
0.057	3 249	66 400	0.89
0.051	2 601	66 600	0.87
0.045	2 025	66 800	0.86
0.040	1 600	67 000	0.85

GROOVED TROLLEY WIRE.

Sections. 10. Standard sections shall be those known as the "American Standard Grooved Trolley Wire Sections," the shape and dimensions of which are as shown in Fig. 1.

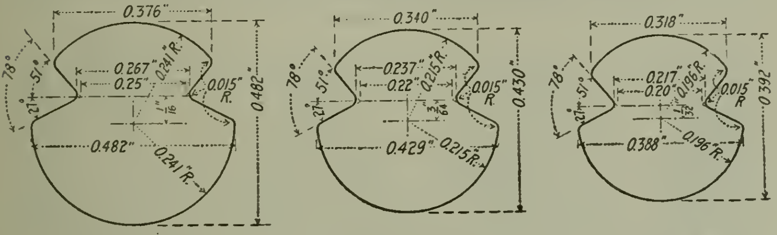
Dimensions and Permissible Variations. 11. (*a*) Size shall be expressed as the area of cross-section in circular mils, the standard sizes being as follows:

211,600 circular mils, weighing 3,386 lb. per mile.
168,100 " " " 2,690 " " "
133,200 " " " 2,132 " " "

(*b*) Grooved trolley wire may vary 4 per cent over or under in weight per unit length from standard, as determined from the nominal cross-section.

Physical Tests. 12. The physical tests shall be made in the same manner as those upon round wire. The tensile strength of grooved wire shall be at least 95 per cent of that required for round wire of the same sectional area; the elongation shall be the same as that required for round wire of the same sectional area.

Electric Resistivity. 13. The requirements for electric resistivity shall be the same as those for round wire of the same sectional area.



211600 C.M.Wire. 168100 C.M.Wire 133200 C.M.Wire

FIG. 1.

FIGURE-EIGHT TROLLEY WIRE.

Sections. 14. Standard sections of figure-eight trolley wire shall be as shown in Fig. 2.

Requirements. 15. The requirements for weight, physical properties, and electric resistivity of figure-eight trolley wire shall be the same as for the same sizes of grooved trolley wire.

EXPLANATORY NOTES ON STANDARD SPECIFICATIONS FOR HARD-DRAWN COPPER WIRE.

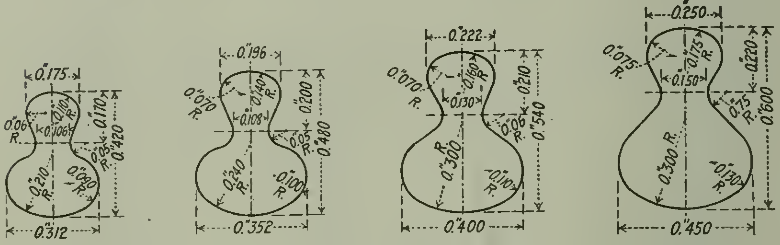
5. The specific gravity of copper was formerly standardized in these specifications at 8.90. The value has been changed to 8.89, since that is the value adopted as standard by the American Institute of Electrical Engineers and the International Electro-Technical Commission.

7. (*a*) The use of arbitrary gage numbers to express dimensions cannot be too strongly condemned. There are many such

gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by workshop tools. Definite diameters in measurable units are evidently preferable.

8. Many other physical tests than those provided in these specifications are included in existing specifications. The reasons for the omission of some of the more common are given as follows:

Twist Tests.—The wire is sometimes required to permit twisting through a stated number of revolutions before breaking. The results are so easily influenced by temperature, speed of rotation, method of gripping, and other variables not easily defined or controlled, that the test is at least of doubtful value.



105,600 C.M.. 133,200 C.M. 168,100 C.M. 211,600 C.M.

FIG. 2.

It is the opinion of the committee[1] that it is impractical to so define the conditions of the test that a twist test can be made definite and reliable; hence there is no warrant for its inclusion in specifications.

Wrap Tests.—Wire is sometimes required to permit tight wrapping about a wire of its own diameter, unwrapping and again re-wrapping. It is obvious that the making of a test of this kind with wire that is already hard-drawn is exceedingly difficult. Every one who has tried to break off a piece of tough wire by bending it back and forth between the fingers, knows how hard it is to confine the bend to one place, because of the hardening action of the previous bends. Hard wire which has been wrapped around a wire of small diameter is hardened still more and it is almost impossible to straighten the wire, let alone re-coil it in the opposite direction. In the opinion of the committee, it is inadvisable to include a test which at best is so indefinite as a wrap test. Furthermore, it is the opinion of the committee that wire which will meet the physical tests included in these specifications will meet any properly made twist or wrap test that would reasonably be required.

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[1] Committee B-1 on Standard Specifications for Copper Wire.

Since the adoption of the Standard Specifications for Hard-Drawn Copper Wire, proposed in 1909, the committee has very carefully considered the matter of twist and wrap tests, and it is their final opinion that while there might be some possible reason for requiring that wire shall stand wrapping around a wire of equal diameter, there can be no good reason for including in specifications the requirement that it shall stand unwrapping and re-wrapping, because such a test is indefinite and cannot be made otherwise. It is almost physically impossible to unwrap and re-wrap hard-drawn wire about a wire of its own diameter. With respect to twist tests, the committee has nothing to add to the statement already on record, condemning this character of test.

Elastic Limit.—During the tension test on wire, there is seldom to be observed any definite drop of the beam or increase in the rate of elongation, corresponding to the yield point commonly observed in testing steel. The only way in which the elastic limit of hard wire may be determined is by the actual plotting of the elastic curve from extensometer readings. Even such tests are difficult of interpretation, because the wire when available for tests is usually curved, due to its having been put up in a coil. There are little sets observable before the true elastic limit has been reached, owing to the fact that one side of the wire, having been stretched in coiling, is really a little harder that the other side, and the pull is, therefore, not even. Considering the difficulty of making the test and the uncertainty of the results obtained, it is the opinion of the committee that it would be inadvisable to include an elastic limit test in these specifications. It is evident that if the designing engineer requires a knowledge of the location of the elastic limit, for purposes of calculation in designing, such data can be obtained by special tests on representative sizes of wire, which will fix the relation of the elastic limit to the ultimate strength for all wire which is properly made.

Tests carefully made by members of the committee show that the elastic limit of hard-drawn copper wire from sizes 0.460 to 0.325 in., inclusive, averages 55 per cent of the ultimate tensile strength required in these specifications, with a minimum value of 50 per cent; for sizes 0.324 to 0.040 in., inclusive, it averages 60 per cent of the ultimate tensile strength required in these specifications, with a minimum value of 55 per cent. This statement of experience is based on the definition of elastic limit as "that point on the elastic curve beyond which the ratio of stress to strain ceases to be constant."

9. *Conductivity.*—Electric conductivity was formerly expressed as a percentage on the basis of a determination made by Matthiessen about 1865, of the electric resistivity of supposedly pure copper. Since that time the methods of refining copper have advanced, so that it is not uncommon to find copper of over 100 per cent conductivity on the Matthiessen basis. There has until recently not been international agreement on the electric resistivity of copper to be considered the standard for the expression of conductivity. While international agreement upon the value 0.15328 ohms per meter-gram at 20° C. for the resistivity of copper equal to 100 per cent conductivity was reached by the International Electro-Technical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.:

900.77 lb. per mile-ohm is equal to:

0.15775 ohms per meter-gram,
1.7745 microhms per centimeter-cube,
0.69863 microhms per inch-cube,
10.674 ohms per mil-foot.

910.15 lb. per mile-ohm is equal to:

0.15940 ohms per meter-gram,
1.7930 michroms per centimeter-cube,
0.70590 microhms per inch-cube,
10.785 ohms per mil-foot.

10. It is obvious that the simplest designation of irregular shapes of similar outline is by sectional area, and the most commonly used unit among electrical engineers is the circular mil. Therefore, while the sizes of grooved trolley wire regularly used are generally known by B & S gage number, corresponding to their sectional area, it has been deemed advisable by the committee to list these sizes, in specifications, by their sectional area expressed in circular mils. The three sizes which are most extensively used commercially are the only ones listed; a fourth size is but little used, and the use is growing less.

11. The only way in which gage variations are easily determinable in irregular shapes is by recourse to weights of standard lengths, and this has been the method adopted in the specifications.

STANDARD SPECIFICATIONS
FOR
MEDIUM HARD-DRAWN COPPER WIRE.

Serial Designation: B 2 – 15.

These specifications are issued under the fixed designation B 2; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1912; Revised, 1913, 1915.

Material. 1. The copper shall be of such quality and purity that when drawn medium-hard, it shall have the properties and characteristics herein required.

Shapes. 2. These specifications cover medium hard-drawn round wire, as hereinafter described.

Finish. 3. (*a*) The wire must be free from all imperfections not consistent with the best commercial practice.

(*b*) Necessary brazes in medium hard-drawn wire must be made in accordance with the best commercial practice, and tests upon a section of wire containing a braze must show at least 95 per cent of the tensile strength of the unbrazed wire. Elongation tests are not to be made upon test sections including brazes.

Packages. 4. (*a*) Packing sizes for round wire shall be agreed upon in the placing of individual orders.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

Specific Gravity 5. For the purpose of calculating weights, cross-sections, etc., the specific gravity of copper shall be taken as 8.89 at 20° C.

Inspection. 6. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material conforms to the requirements of these specifications.

Medium Hard-Drawn Round Wire.

Dimensions and Permissible Variations. 7. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; that is, in mils.

(*b*) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.100 in. in diameter and larger, one per cent over or under;

For wire less than 0.100 in. in diameter, one mil over or under.

(*c*) Each coil is to be gaged at three places, one near each end, and one approximately at the middle; the coil may be rejected, if, two points being within the accepted limits, the third point is off gage more than 2 per cent in the case of wire 0.064 in. in diameter and larger, or more than 3 per cent in the case of wire less than 0.064 in. in diameter.

TABLE I.

Diameter, in.	Tensile Strength, lb. per sq. in.		Elongation in 10 in. per cent.
	Minimum.	Maximum.	
0.460	42 000	49 000	3.75
0.410	43 000	50 000	3.6
0.365	44 000	51 000	3.25
0.325	45 000	52 000	3.0
0.289	46 000	53 000	2.75
0.258	47 000	54 000	2.5
0.229	48 000	55 000	2.25
			in 60 in.
0.204	48 330	55 330	1.25
0.182	48 600	55 660	1.20
0.162	49 000	56 000	1.15
0.144	49 330	56 330	1.11
0.128	49 660	56 660	1.08
0.114	50 000	57 000	1.06
0.102	50 330	57 330	1.04
0.091	50 660	57 660	1.02
0.081	51 000	58 000	1.00
0.072	51 330	58 330	0.98
0.064	51 660	58 660	0.96
0.057	52 000	59 000	0.94
0.051	52 330	59 330	0.92
0.045	52 660	59 660	0.90
0.040	53 000	60 000	0.88

Physical Tests.

8. Wire shall be so drawn that its tensile strength shall not be greater than the maximum values and not less than the minimum values stated in Table I, and its elongation shall not be less than the minimum values stated in Table I. Tension tests shall be made upon fair samples, and the elongation of wire larger in diameter than 0.204 in. shall be determined as the permanent increase in length, due to the breaking of the wire in

tension, measured between bench marks placed upon the wire originally 10 in. apart. The elongation of wire 0.204 in. in diameter and smaller shall be determined by measurements made between the jaws of the testing machine. The zero length shall be the distance between the jaws when a load equal to 10 per cent of the required ultimate breaking strength shall have been applied, and the final length shall be the distance between the jaws at the time of rupture. The zero length shall be as near 60 in. as possible. The fracture shall be between the bench marks in the case of wire larger than 0.204 in. in diameter and between the jaws in the case of smaller wire, and not closer than 1 in. to either bench mark or jaw. If upon testing a sample from any coil of wire, the results are found to be below the values stated in the table, tests upon two additional samples shall be made, and the average of the three tests shall determine acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in the table.

Electric Resistivity

9. Electric resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.).

The wire shall not exceed the following limits:

For diameters 0.460 in. to 0.325 in., 896.15 lb. per mile-ohm at 20° C.

For diameters 0.324 in. to 0.040 in., 905.44 lb. per mile-ohm at 20° C.

EXPLANATORY NOTES.

Definition.—Medium Hard-Drawn Wire is essentially and necessarily a special product, because when wire has once started on its course through the drawing operations, it can only finish as a hard-drawn wire to be used as such or to be annealed and become soft or annealed wire. Medium hard-drawn wire is annealed wire drawn to a slightly smaller diameter.

5. The specific gravity of copper was formerly standardized in these specifications at 8.90. The value has been changed to 8.89, since that is the value adopted as standard by the American Institute of Electrical Engineers and the International Electro-Technical Commission.

7. (*a*) The use of arbitrary gage numbers to express dimensions cannot be too strongly condemned. There are many such

gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by work-shop tools. Definite diameters in measureable units are evidently preferable.

8. Medium hard-drawn wire approaches hard-drawn wire in its characteristics, but from the very nature of the product, exact uniformity in tensile strength cannot be obtained; hence, the necessity for establishing a range of tensile strength within which standard medium hard-drawn wire must be expected to be found. In the opinion of the committee,[1] any narrowing or reduction in the range permitted in tensile strength can only result in an unjustifiable increase in the cost of production of the wire.

Many other physical tests than those provided in these specifications are included in existing specifications. The reasons for the omission of some of the more common are given as follows:

Twist Tests.—The wire is sometimes required to permit twisting through a stated number of revolutions before breaking. The results are so easily influenced by temperature, speed of rotation, method of gripping, and other variables not easily defined or controlled, that the test is at least of doubtful value. It is the opinion of the committee that it is impractical to so define the conditions of the test that a twist test can be made definite and reliable; hence there is no warrant for its inclusion in specifications.

Wrap Tests.—Wire is sometimes required to permit tight wrapping about a wire of its own diameter, unwrapping and again re-wrapping. It is obvious that the making of a test of this kind with wire that is already hard is exceedingly difficult. Every one who has tried to break off a piece of tough wire by bending it back and forth between the fingers, knows how hard it is to confine the bend to one place, because of the hardening action of the previous bends. Hard wire which has been wrapped around a wire of small diameter is hardened still more and it is almost impossible to straighten the wire, let alone re-coil it in the opposite direction. In the opinion of the committee, it is inadvisable to include a test which at best is so indefinite as a wrap test. Furthermore, it is the opinion of the committee that wire which will meet the physical tests included in these specifications will meet any properly made twist or wrap test that would reasonably be required

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[1] Committee B-1 on Standard Specifications for Copper Wire.

The committee has carefully considered the matter of twist and wrap tests in connection with both hard-drawn and medium hard-drawn wire, and it is their final opinion that while there might be some possible reason for requiring that wire shall stand wrapping around a wire of equal diameter, there can be no good reason for including in specifications the requirement that it shall stand unwrapping and re-wrapping, because such a test is indefinite and cannot be made otherwise. It is almost physically impossible to unwrap and re-wrap hard-drawn wire about a wire of its own diameter.

Elastic Limit.—During the tension test on wire, there is seldom to be observed any definite drop of the beam or increase in the rate of elongation, corresponding to the yield point commonly observed in testing steel. The only way in which the elastic limit of hard wire may be determined is by the actual plotting of the elastic curve from extensometer readings. Even such tests are difficult of interpretation, because the wire when available for tests is usually curved, due to its having been put up in a coil. There are little sets observable before the true elastic limit has been reached, owing to the fact that one side of the wire, having been stretched in coiling, is really a little harder than the other side, and the pull is, therefore, not even. Considering the difficulty of making the test and the uncertainty of the results obtained, it is the opinion of the committee that it would be inadvisable to include an elastic limit test in these specifications. It is evident that if the designing engineer requires a knowledge of the location of the elastic limit, for purposes of calculation in designing, such data can be obtained by special tests on representative sizes of wire, which will fix the relation of the elastic limit to the ultimate strength for all wire which is properly made.

Tests carefully made by members of the committee show that the elastic limit of medium hard-drawn wire averages 50 per cent of the ultimate tensile strength required in these specifications. This statement of experience is based on the definition of elastic limit as "that point on the elastic curve beyond which the ratio of stress to strain ceases to be constant."

9. *Conductivity.*—Electric conductivity was formerly expressed as a percentage on the basis of a determination made by Matthiessen about 1865, of the electric resistivity of sup-

posedly pure copper. Since that time the methods of refining copper have advanced, so that it is not uncommon to find copper of over 100 per cent conductivity on the Matthiessen basis. There has until recently not been international agreement on the electric resistivity of copper to be considered the standard for the expression of conductivity. While international agreement upon the value 0.15328 ohms per meter-gram at 20° C. for the resistivity of copper equal to 100 per cent conductivity was reached by the International Electro-Technical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any one of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.:

896.15 lb. per mile-ohm is equal to:

0.15694 ohms per meter-gram,
1.7654 microhms per centimeter-cube,
0.69504 microhms per inch-cube,
10.619 ohms per mil-foot.

905.44 lb. per mile-ohm is equal to:

0.15857 ohms per meter-gram,
1.7837 microhms per centimeter-cube,
0.70224 microhms per inch-cube,
10.729 ohms per mil-foot.

STANDARD SPECIFICATIONS
FOR
SOFT OR ANNEALED COPPER WIRE.

Serial Designation: B 3 – 15.

These specifications are issued under the fixed designation B 3; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1912; Revised, 1913, 1915.

These specifications were approved June 15, 1921,
as "Tentative American Standard" by the
American Engineering Standards Committee.

Material. 1. The copper shall be of such quality and purity that, when drawn and annealed, it shall have the properties and characteristics herein required.

Shapes. 2. These specifications cover untinned drawn and annealed round wire.

Finish. 3. (*a*) The wire must be free from all imperfections not consistent with the best commercial practice.

(*b*) Necessary brazes in soft or annealed wire must be made in accordance with the best commercial practice.

Packages. 4. (*a*) Wire may be shipped in coils or on reels as agreed upon by the purchaser and manufacturer. In Table I there are stated the maximum and minimun weights of wire of the stated sizes which may be shipped in any one package, whether coil, reel or spool; in the case of wire larger than 0.010 in. in diameter, the maximum and minimum package weights are net, and in the case of wire 0.010 in. and less in diameter, the maximum package weights are gross, and the minimum package weights are net. The table also states the limiting dimensions of the coils, reels and spools on which wire may be shipped. The length and diameter stated for reels and spools are to be measured overall and are maximum sizes; reels or spools smaller than these may be used provided the minimum weights called for are carried by the reel or spool. In the table, there are also stated the diameters of the draw-block on which the final drawing of the wire is to be made, when wire is shipped in coils; it being understood that the wire is not to be re-wound after final drawing. This provision is made to insure that coils of wire of a given gage, when supplied by different manufacturers, will be of the same general dimensions.

Wire 0.204 in. in diameter and larger may be shipped in larger packages when agreed upon.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

Specific Gravity.

5. For the purpose of calculating weights, ,cross-sections etc., the specific gravity of copper shall be taken as 8.89 at 20° C.

Dimensions and Permissible Variations.

6. (*a*) Size shall be expressed as the diameter of the wire in decimal fractions of an inch.

(*b*) Wire shall be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.010 in. in diameter and larger, one per cent over or under;

For wire less than 0.010 in. in diameter, 0.1 mil (0.0001 in.) over or under.

TABLE I.

Diameters, in.	Package Weights, lb.		Diam. of Draw-Block, in.	Dimensions of Reels and Spools, in.		
	Max.	Min.		Max. Dia.	Max. Length.	Diameter of Hole for Rod.
0.460 to 0.360	520	290	24	32	21	1½ to 2½
0.359 " 0.258	430	290	24	32	21	1½ " 2½
0.257 " 0.129	290	140	22	24	12	1½ " 2½
0.128 " 0.102	230	95	22	24	12	⅝ " 1½
0.101 " 0.083	230	75	22	24	12	⅝ " 1½
0.082 " 0.081	200	75	16	24	12	⅝ " 1½
0.080 " 0.064	200	50	16	24	12	⅝ " 1½
0.063 " 0.051	120	50	16	24	10	⅝ " 1½
0.050 " 0.041	100	50	16	24	10	⅝ " 1½
0.040 " 0.032	50	20	8	24	8	⅝ " 1⅛
0.031 " 0.020	25	15	8	10	6½	⅝ " ⅞
0.019 " 0.011	10	5	8	5½	4	⅜ " $\frac{11}{16}$
0.010 " 0.008	5	2½	8	4	4	⅜ " $\frac{11}{16}$
0.007 " 0.0056	2½	1	6	2½	4	⅜ " $\frac{11}{16}$
0.005	1½	⅝	6	2½	4	⅜ " $\frac{11}{16}$
0.004	1½	⅜	6	2½	4	⅜ " $\frac{11}{16}$
0.003	1	¼	6	2½	4	⅜ " $\frac{11}{16}$

(*c*) Each coil shall be gaged at three places, one near each end and one approximately at the middle; from spools, approximately 12 ft. shall be reeled off, the wire shall be gaged in six places between the second and twelfth foot from the end. The coils or spools will be rejected if the average of the measurements obtained is not within the limits specified in Paragraph (*b*).

Physical Tests.

7. Wire shall be so drawn and annealed that its tensile strength shall not be greater than the value stated in Table II and its elongation not less than the value stated in Table II. Tensile tests shall be made upon fair samples, and the elongation shall be determined as the permanent increase in length, due

to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The fracture shall be between the bench marks and not closer than 1 in. to either bench mark. If upon testing a sample from any coil, reel or spool of wire, the results are found to be below the stated value in elongation or above the stated value in tensile strength, tests upon two additional samples shall be made, and the average of the three tests shall determine acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in Table II.

TABLE II.

Diameter, in.	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent.
0.460 to 0.290	36 000	35
0.289 " 0.103	37 000	30
0.102 " 0.021	38 500	25
0.020 " 0.003	40 000	20

Electric Resistivity. 8. Electric resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.), and it shall not exceed 891.58 lb. per mile-ohm.

Inspection 9. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material conforms to the requirements of these specifications.

EXPLANATORY NOTES.

Soft or annealed copper wire is wire which has been drawn by customary operations and annealed, and finished by cleaning when necessary to remove scale or oxide. The wire is so soft and ductile that it is easily marred and even stretched by careless handling in the operations of winding or cabling, hence the necessity for confining specifications and inspection to wire in packages as it leaves the manufacturer, and before being put through processes incident to its use by the purchaser.

4. (*a*) Attention is called to the necessity for the purchaser and manufacturer agreeing on the package weights which will be standard under any individual contract. The committee[1] has indicated limitations to standard package weights which in their opinion will provide packages of sufficient size to be desirable, and without being so large that the wire is apt to be damaged in handling.

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[1] Committee B-1 on Standard Specifications for Copper Wire.

5. The specific gravity of copper was formerly standardized in these specifications at 8.90. The value has been changed to 8.89, since that is the value adopted as standard by the American Institute of Electrical Engineers and the International Electro-Technical Commission.

6. The use of arbitary gage numbers to express dimensions cannot be too strongly condemned. There are many such gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by workshop tools. Definite diameters in measureable units are evidently preferable.

8. Electric conductivity was formerly expressed as a percentage on the basis of a determination made by Matthiessen about 1865, of the electric resistivity of supposedly pure copper. Since that time the methods of refining copper have advanced, so that it is not uncommon to find copper of over 100 per cent conductivity on the Matthiessen basis. There has until recently not been international agreement on the electric resistivity of copper to be considered the standard for the expression of conductivity. While international agreement upon the value 0.15328 ohms per meter-gram at 20° C. for the resistivity of copper equal to 100 per cent conductivity was reached by the International Electro-Technical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any one of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.:

891.58 lb. per mile-ohm is equal to:

0.15614 ohms per meter-gram,
1.7564 microhms per centimeter-cube.
0.69150 microhms per inch-cube,
10.565 ohms per mil-foot.

STANDARD SPECIFICATIONS

FOR

TINNED SOFT OR ANNEALED COPPER WIRE FOR RUBBER INSULATION.

Serial Designation: B 33 – 21.

These specifications are issued under the fixed designation B 33; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1919; Adopted, 1921.

Product Covered. 1. These specifications cover tinned soft or annealed copper wire suitable for use in making rubber insulated wires and cables.

I. MANUFACTURE.

Manufacture. 2. The tinned wire shall be made by coating soft or annealed copper wire with pure tin. The copper used shall be of such quality and purity that after tinning it shall have the properties and characteristics hereinafter required.

II. CHEMICAL PROPERTIES AND TESTS.

Continuity of Coating. 3. The continuity of the tin coating shall be determined by the Sodium Polysulfide test, which shall be applied as specified in Sections 4 to 10.

(*A*) *Treatment of Samples.*

Length of Samples. 4. Samples shall have a length of about 6 in., and they shall be tagged or marked to correspond with the coil or reel from which they were cut.

Treatment of Samples. 5. The samples shall be thoroughly cleaned by immersion in benzine, redistilled petroleum ether, ether, or carbon tetrachloride for at least 3 minutes, then removed and wiped dry with a clean, soft cloth. The samples thus cleaned shall be kept in a clean, dry cloth until tested. The part of the sample to be immersed in the test solution shall not be handled. Care shall be taken to avoid abrasion by the cut ends.

(*B*) *Method of Testing.*

Immersion of Samples.

6. (*a*) A length of at least 4½ in. of the cleaned samples shall be immersed, in accordance with the following cycles, in test solutions maintained at a temperature between 15.5 and 21° C. (60 and 70° F.):

First: Immerse for 1 minute in HCl solution as hereinafter defined. Wash and wipe dry.

Second: Immerse for 30 seconds in sodium-polysulfide solution as hereinafter defined. Wash and wipe dry.

Third: Immerse for 1 minute in HCl solution. Wash and wipe dry.

Fourth: Immerse for 30 seconds in sodium-polysulfide solution. Wash and wipe dry.

(*b*) After each immersion the samples shall be immediately and thoroughly washed in clean water and wiped dry with a clean, soft cloth.

Examination of Samples.

7. After the above-described operations, the samples shall be examined in order to ascertain if copper exposed through openings in the tin coating has been blackened by the action of the sodium polysulfide. The sample shall be considered to have failed if by such blackening exposed copper is revealed. No attention shall be paid to blackening within ½ in. of the cut end.

Mechanical Test for Adhesion.

8. A mechanical test for adhesion of tinning may be made by bending the wire around a rod having a diameter equal to four times the diameter of the wire, and dipping the bent portion of the wire in the sodium-polysulfide solution only, for 30 seconds. Any cracking or parting of the coating will be shown by blackening of the copper. Such cracking or parting of the coating will be a cause for rejection.

(*C*) *Testing Solution.*

9. (*a*) The hydrochloric-acid solution, specific gravity 1.088, shall be made in the following manner: Commercial HCl, sp. gr. 1.12, shall be diluted with distilled water to a specific gravity of 1.088 measured at 15°.5 C. (60° F.).

(*b*) A portion of HCl solution having a volume of 180 cc. shall be considered exhausted when there have been immersed in it for two cycles the number of test samples of any size as indicated in the following table:

DIAMETER, IN.	MAXIMUM NUMBER TO BE TESTED FOR TWO CYCLES IN 180 CC. OF ACID SOLUTION.
0.460 to 0.141	2
0.140 to 0.086	4
0.085 to 0.051	6
0.050 to 0.039	10
0.038 to 0.031	12
0.030 to 0.003	14

For wire whose diameter is between listed sizes, the number of samples shall be the same as for the next larger size indicated.

Sodium-Polysulfide Solution.

10. The sodium-polysulfide test solution, sp. gr. 1.142, shall be made in the following manner: A concentrated solution shall be made by dissolving sodium-sulfide crystals in distilled water until the solution is saturated at about 21° C. (70° F.), adding about 250 g. of flowers of sulfur per liter, and allowing to stand for at least 24 hours.

TABLE I.—TENSILE PROPERTIES.

Diameter, in.	Tensile Strength, max., lb. per sq. in.	Elongation in 10 in., min., per cent.
0.460 to 0.290	36 000	30
0.289 to 0.103	37 000	25
0.102 to 0.021	38 500	20
0.020 to 0.012	39 000	15
0.011 to 0.003	40 000	10

The test solution shall be made by diluting a portion of the concentrated solution with distilled water to a specific gravity of 1.142 at 15°.5 C. (60° F.). The sodium-polysulfide test solution should have sufficient strength to blacken thoroughly a piece of clean untinned copper wire in 5 seconds. A portion of test solution used for testing samples will not be considered exhausted until it fails to blacken a piece of clean copper as above described.

III. PHYSICAL PROPERTIES AND TESTS.

(*A*) *Mechanical.*

Tensile Properties.

11. (*a*) The tensile strength and elongation of the tinned copper wire shall conform to the values in Table I.

(*b*) For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size indicated in Table I.

(*B*) *Electrical.*

12. The resistivity of the wire expressed in pounds per mile ohm at 20° C. (68° F.) shall not exceed the values in Table II. **Resistivity.**

IV. PERMISSIBLE VARIATIONS.

13. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch. **Permissible Variations.**

(*b*) The permissible variation from nominal diameter shall be:

For wire 0.010 in. or over in diameter, 1 per cent under and 3 per cent over;

For wire under 0.010 in. in diameter, 0.0001 in. under and 0.0003 in. over.

(*c*) For coiled wire, each coil shall be gaged in three places; one near each end, and one approximately at the middle. For spools, approximately 12 ft. shall be reeled off and the wire shall be gaged in six places between the second and twelfth foot from the end.

TABLE II.—RESISTIVITY.

Diameter, in.	Resistivity, lb. per mile ohm at 20° C.
0.460 to 0.290	896.15
0.289 to 0.103	900.77
0.102 to 0.021	910.15
0.020 to 0.012	929.52
0.011 to 0.003	939.51

(*d*) The coil or spool will be rejected if the average gage is not within the limits specified in Paragraph (*b*).

V. WORKMANSHIP AND FINISH.

14. The tin coating shall consist of a smooth continuous layer, firmly adherent to the surface of the copper. **Workmanship.**

VI. INSPECTION AND REJECTION.

15. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. **Inspection.**

16. Wire which shows exposed copper by blackening after testing in the sodium-polysulfide solution, as described, or which fails to conform with the other requirements of these specifications, shall be rejected. **Rejection.**

EXPLANATORY NOTE.

The coating of tin on copper wire is for the purpose of protecting the copper against the action of the rubber insulation. It is, therefore, necessary that the coating be continuous. The test in the sodium-polysulfide is for the purpose of determining whether or not the wire carries a continuous envelope of pure tin.

The thickness of the tin coating is necessarily varied. Under the same conditions of tinning the coating on all sizes of wire, excepting on fine wire, is approximately the same. The coating on fine wire is generally relatively heavier than that on coarse wire. It is not, therefore, correct to apply a larger number of cycles in the test on coarse wire than is applied to fine wire. It is probable that one cycle of the dip test would be sufficient to discover defects in tinned wire, but in order to make certain that no partially covered spots may escape attention, two cycles have been provided for. It has been found that the tin coating on copper wire consists of two parts, an envelope of pure tin on the outside, with an intermediate layer of copper-tin alloy. This tin alloy, as well as the amount of tin present, has an effect on the resistivity of the wire. Since the relative amount of tin coating and alloy is greater on the small wire than it is on the coarser wire, the resistivity of the wire increases as the size decreases. This also accounts for the decrease in elongation due to tinning soft wire.

STANDARD SPECIFICATIONS
FOR
BARE CONCENTRIC-LAY COPPER CABLE: HARD, MEDIUM-HARD, OR SOFT.

Serial Designation: B 8 – 21.

These specifications are issued under the fixed designation B 8; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1921.

I. MANUFACTURE.

Products Covered.

1. (*a*) These specifications cover bare concentric-lay cables made from round copper wires laid helically around a central core in one or more layers. The central core shall be made of wire having the same quality and temper as the concentric layers, unless otherwise especially provided for in separate specifications governing the individual case.

Classes.

(*b*) The purposes for which the several classes of concentric-lay cables are generally used are as follows:

Class A, for bare, weatherproof, slow-burning, and slow-burning weatherproof cable for aerial use;

Class B, for various insulated cable, such as rubber, paper, varnished cloth, etc.;

Class C, for cable where greater flexibility is required than in Class B.

Requirements of Wires.

2. The copper wires entering into the construction of standard concentric-lay cable shall, before stranding, meet all the requirements of that one of the Standard Specifications of the American Society for Testing Materials for Hard-Drawn, Medium Hard-Drawn, Soft or Annealed or Tinned Soft Copper Wire (Serial Designations: B 1, B 2, B 3, or B 33), which applies.

Brazes.

3. Brazes may be made in the wire when finished and ready for cabling. Such brazes shall be made in accordance with the best commercial practice. No brazes in cable made from hard, or medium hard-drawn copper wire may be closer together than 50 ft.

Pitch and Lay.

4. The pitch of standard cable shall not be less than 12 nor more than 16 diameters of the cable, and the lay may be right or left-handed, unless one direction of lay is specified by the purchaser.

II. PHYSICAL PROPERTIES AND TESTS.

Testing. 5. (*a*) Tests for the physical and electrical properties of the wires composing cables made from hard-drawn or medium hard-drawn wire may be made before but not after stranding.

(*b*) Tests for the physical and electrical properties of wires composing cables made from annealed copper wire or from tinned soft copper wire may be made on wires removed from the cable in which case the maximum tensile strength permitted shall be increased 5 per cent and the minimum elongation permitted shall be reduced 5 per cent. Care must be taken to avoid mechanical injury of wire removed from cable for the purpose of testing.

(*c*) Experience indicates that the tensile strength of concentric-lay copper cable of standard pitch is at least 90 per cent of the total strength required of the wires forming the cable.

Weights and Area. 6. For the purpose of calculating weights, cross-sections, etc., the specific gravity of copper shall be taken as 8.89 at 20° C. The resistance and mass of a stranded conductor are greater than in a solid conductor of the same cross-sectional area, depending on the lay (that is, the pitch of the twist of the wires). Two per cent shall be taken as the standard increment of resistance and of mass. In cases where the lay is definitely known, the increment shall be calculated and not assumed.

Variation in Area. 7. The area of cross-section of the completed cable shall not be more than 2 per cent below the area specified, as determined by weight.

Construction. 8. The area of cross-section, number and diameter of wires, in standard cable Classes A, B, and C, shall be as specified in Table I.

III. PACKING AND SHIPPING.

Packing and Shipping. 9. (*a*) Package sizes for cable shall be agreed upon in the placing of individual orders.

(*b*) The cable shall be protected against damage in ordinary handling and transportation.

IV. INSPECTION.

Inspection. 10. (*a*) All testing and inspection, both of individual wires entering into the construction of the cable, and of the completed cable, shall be made at the place of manufacture. Tests on individual wires shall be made on samples taken before cabling, and not on wires removed from the completed cable except as provided in Section 5 (*b*).

(*b*) The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material conforms to the requirements of these specifications.

TABLE I.

Area of Cross-Section, circular mils.	Approximate A. W. G. or B. & S. Gage Sizes.	CLASS A.		CLASS B.		CLASS C.	
		Number of Wires.	Diameter of Wires, mils.	Number of Wires.	Diameter of Wires, mils.	Number of Wires.	Diameter of Wires, mils.
2 000 000	....	91	148.2	127	125.5	169	108.8
1 900 000	....	91	144.5	127	122.3	169	106.0
1 800 000	....	91	140.6	127	119 1	169	103.2
1 700 000	....	91	136.6	127	115.7	169	100.3
1 600 000	....	91	132.6	127	112.2	169	97.3
1 500 000	....	61	156.8	91	128 4	127	108.7
1 400 000	....	61	151.5	91	124.0	127	105.0
1 300 000	....	61	146.0	91	119.5	127	101.2
1 250 000	....	61	143.2	91	117.2	127	99.2
1 200 000	....	61	140.3	91	114.8	127	97.2
1 100 000	....	61	134.3	91	109.9	127	93.1
1 000 000	....	61	128.0	61	128.0	91	104.8
950 000	....	61	124.8	61	124.8	91	102.2
900 000	....	61	121.5	61	121.5	91	99.4
850 000	....	61	118.0	61	118.0	91	96.6
800 000	....	61	114.5	61	114.5	91	93.8
750 000	....	61	110.9	61	110.9	91	90.8
700 000	....	61	107.1	61	107.1	91	87.7
650 000	....	61	103.2	61	103.2	91	84.5
600 000	....	37	127.3	61	99.2	91	81.2
550 000	....	37	121.9	61	95 0	91	77.7
500 000	....	37	116.2	37	116.2	61	90.5
450 000	....	37	110.3	37	110.3	61	85.9
400 000	....	19	145.1	37	104 0	61	81.0
350 000	....	19	135.7	37	97.3	61	75.7
300 000	....	19	125.7	37	90.0	61	70.1
250 000	....	19	114.7	37	82.2	61	64.0
212 000	4/0	7-19	173.9-105.5	19	105.5	37-61	75.6-58.9
168 000	3/0	7-19	155.0-94.0	19	94.0	37-61	67.3-52.5
133 000	2/0	7	138.0	19	83.7	37	60.0
106 000	1/0	7	122.8	19	74.5	37	53.4
83 750	1	7	109.3	19	66.4	37	47.6
66 400	2	7	97.4	7	97.4	19	59.1
52 600	3	7	86.7	7	86.7	19	52.6
41 700	4	7	77.2	7	77.2	19	46.9
33 100	5	7	68.8	7	68.8	19	41.7
26 300	6	7	61.2	7	61.2	19	37.2
20 800	7	7	54.5	7	54.5	19	33.1
16 500	8	7	48.6	7	48.6	19	29.5

NOTE.—Class A cable, sizes 4/0 and 3/0, is usually 7-strand when bare and 19-strand when weatherproof, etc.

V. DEFINITION OF TERMS.

Concentric-Lay Cable.

11. *Concentric-Lay Cable.*—A single conductor cable composed of a central core surrounded by one or more layers of helically laid wires.

Lay.

12. *Lay.*—The lay of a cable is the length expressed in inches for each complete turn of the wire around the axis, measured along its axis.

Direction of Lay.

13. *Direction of Lay.*—The direction of lay is the lateral direction in which the strands of a cable run over the top of the cable as they recede from an observer looking along the axis of the cable.

EXPLANATORY NOTES.

1. *Classes of Cable.*—These specifications have been drawn to cover cables made from hard-drawn, medium hard-drawn, and soft copper wire, since the manufacturing of cables from the various classes of wire is similar, and the physical properties of the cable depend upon, and are usually expressed in, terms of those of the class of wire employed.

2. *Physical Properties.*—The accurate testing of cable for its physical properties is practically impossible in commercial laboratories. In order to do this, it is necessary to use long lengths and hold the samples in such a way that the wires shall all be in equal tension. Otherwise the strength will be considerably below the actual strength of the cable. A much more accurate idea of the quality of the cable may be obtained by testing the individual wires before cabling than by attempting tests of the physical properties of the finished cable.

Wires unlaid from cable will manifestly have different physical and electrical properties from those of the wire when prepared for cabling, on account of the deformation brought about by laying and again straightening for test.

3. *Stranding Table.*—The stranding table covers present practice. Class A covers the usual bare and weatherproof construction. Class B is the same as adopted by the Standards Committee of the American Institute of Electrical Engineers, and is given in the Bureau of Standards Circular No. 31, Table XII.

In Class C the figures are those of the Bureau of Standards, Circular No. 31, Table XII, with additions to cover well-established practice. There is need for a table to cover extra-flexible stranding from soft wire, but there are differences of opinion in regard to what should become standard practice. The Standards Committee of the A. I. E. E. have this matter under consideration, and it has seemed best not to attempt to include figures for extra-flexible stranding in this specification. The stranding table will necessarily be the subject of revision which will be undertaken in cooperation with the Standards Committee of the A. I. E. E.

STANDARD SPECIFICATIONS
FOR
HIGH-STRENGTH BRONZE TROLLEY WIRE, ROUND AND GROOVED: 40 AND 65-PER-CENT CONDUCTIVITY.

Serial Designation: B 9 – 16.

These specifications are issued under the fixed designation B 9; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1916.

I. MANUFACTURE.

Shapes. 1. These specifications cover round and grooved bronze trolley wire.

Material. 2. The material used shall be bronze of such nature and composition as to secure, by proper treatment, the qualities hereinafter specified for the finished wire. Bronze of two qualities may be required—one to have a conductivity of 40 per cent, and the other a conductivity of 65 per cent.

Brazes. 3. Necessary brazes in trolley wire shall be made in accordance with the best commercial practice, and tests upon a section of wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire.

Elongation tests shall not be made on test sections including brazes.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 4. (*a*) Round wire shall conform to the requirements as to tensile properties specified in Table I.

(*b*) The tensile strength of grooved wire shall be at least 95 per cent of that required for round wire of the same sectional area; the elongation of grooved wire shall be the same as that required for round wire of the same sectional area.

Tension Test Specimens. 5. Tension tests shall be made upon fair samples, and the elongation of the wire shall be determined as permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The fracture shall be between the bench marks, and not closer than 1 in. to either mark. If, upon testing a sample from any coil or reel of wire, the results are found to be below the value stated in the table, tests on two additional samples shall be made, and the average of the three tests shall determine the acceptance or rejection of the coil or reel.

Conductivity.

6. (*a*) Round wire, known as "40-per-cent Conductivity," shall have a conductivity of not less than 40 per cent, figured according to the International Annealed Copper Standard, which is 0.15328 ohms per meter-gram at 20° C.

Round wire, known as "65-per-cent Conductivity," shall have a conductivity of not less than 65 per cent, figured according to the same standard.

TABLE I.

40-PER-CENT CONDUCTIVITY BRONZE.

Diameter, in.	Area, circular mils.	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent.
0.460	211 600	69 200	3.00
0.410	168 100	69 700	3.00
0.365	133 225	71 700	2.50
0.325	105 625	77 100	2.25

65-PER-CENT CONDUCTIVITY BRONZE.

Diameter, in.	Area, circular mils.	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent.
0.460	211 600	59 300	3.00
0.410	168 100	59 800	3.00
0.365	133 225	61 600	2.50
0.325	105 625	66 300	2.25

(*b*) The requirements for conductivity of grooved wire shall be the same as those for round wire of the same sectional area.

III. STANDARD SIZES AND DIMENSIONS.

Dimensions and Permissible Variations of Round Wire.

7. (*a*) The size of round wire shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals, that is, in mils.

(*b*) Round wire is expected to be accurate in diameter. Variations of one per cent over or under nominal diameter shall be permissible.

Standard Sections, Dimensions and Permissible Variations of Grooved Wire

8. (*a*) Standard sections of grooved trolley wire shall be those known as the "American Standard Grooved Trolley Wire Sections," the shape and dimensions of which are shown in Fig. 1.

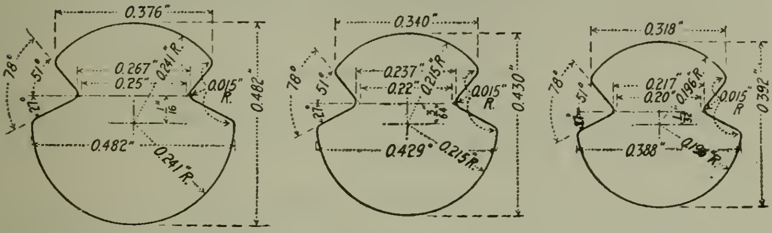
(*b*) The size of grooved wire shall be expressed as the area of cross-section in circular mils, the standard sizes being as follows:

211,600	circular mils, weighing..............	3,386 lb. per mile
168,100	" " "	2,690 " " "
133,200	" " "	2,132 " " "

(*c*) Grooved trolley wire may vary 4 per cent over or under in weight per unit length from standard as determined from the nominal cross-section.

IV. WORKMANSHIP AND FINISH.

Finish. 9. The wire shall be free from all imperfections not consistent with the best commercial practice.



211600 C.M.Wire. 168100 C.M.Wire 133200 C.M.Wire

FIG. 1.

V. PACKING AND SHIPPING.

Packing and Shipping. 10. All wire shall be furnished on substantial reels, suitable for the weight of the wire handled, and shall be protected against damage in ordinary handling and transportation. The length or weight of wire to be wound upon reels shall be agreed upon in placing individual orders.

VI. INSPECTION.

Inspection. 11. (*a*) All testing and inspection shall be made at the place of manufacture.

(*b*) The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material conforms to the requirements of these specifications.

STANDARD SPECIFICATIONS
FOR
MANGANESE-BRONZE INGOTS FOR SAND CASTINGS.

Serial Designation: B 7 – 14.

These specifications are issued under the fixed designation B 7; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1911; Revised, 1914.

Material Covered.

1. These specifications cover the copper-zinc alloy known commercially as manganese-bronze.

I. MANUFACTURE.

Size of Ingots.

2. The bronze shall be cast in the form of ingots having notched flat bottoms, approximately 3 by $2\frac{3}{4}$ in. wide by 12 in. long, properly tapered to strip easily from an iron mold.

II. CHEMICAL PROPERTIES.

Chemical Composition.

3. The bronze shall conform to the following requirements as to chemical composition:

Copper	53 to 62	per cent
Zinc	36 to 54	"
Aluminum	0.05 to 0.5	"
Lead	not over 0.15	"

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

4. The bronze shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	70 000
Elongation in 2 in., per cent	20

Tension Test Specimens.

5. (*a*) The tension test specimen shall be cut from one corner near the bottom of the test ingot.

(*b*) The specimen shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

6. (*a*) One test ingot shall be selected by the inspector to represent 10,000 lb. of ingots or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case two additional tests may be selected by the inspector from the same lot, and tested to represent the lot.

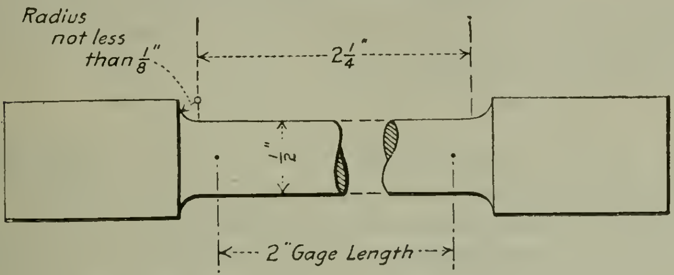
IV. MARKING.

Marking. 7. Each ingot shall be stamped with its proper heat or charge number.

V. INSPECTION AND REJECTION.

Inspection. 8. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturers' works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

Rejection. 9. (*a*) If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 or 4, all ingots in such lot will be rejected, irrespective of the heat or heats from which the test ingots are selected.

(*b*) Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and, if rejected, shall be replaced by the manufacturer free of cost to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

STANDARD SPECIFICATIONS

FOR

THE ALLOY: COPPER, 88 PER CENT; TIN, 10 PER CENT; ZINC, 2 PER CENT.

Serial Designation: B 10 – 18.

These specifications are issued under the fixed designation B 10; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1915; ADOPTED, 1918.

Material Covered.

1. (*a*) These specifications cover the alloy commercially known as government bronze, admiralty gun-metal, gun-metal, or 88–10–2 mixture, when used in castings.

(*b*) It is recommended that this alloy shall not be used where castings are subjected to a temperature exceeding 260° C. (500° F.).

I. MANUFACTURE.

Process.

2. The alloy may be made by any approved method.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The alloy shall conform to the following requirements as to chemical composition:

Copper	86–89 per cent.
Tin	8–11 "
Zinc	1– 3 "

Chemical Analysis.

4. An analysis of each melt shall be made by the manufacturer. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

Sampling.

5. (*a*) The sample for chemical analysis may be taken either by sawing, drilling or milling the casting or tension test specimen and shall represent the average cross-section of the piece.

(*b*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the saw dust or metal chips shall be carefully treated with a magnet to remove any particles of iron derived from the tools.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. The alloy shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	30 000
Elongation in 2 in., per cent	14

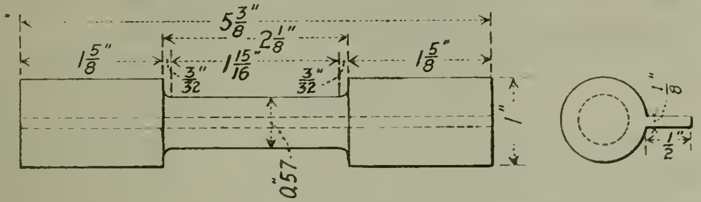
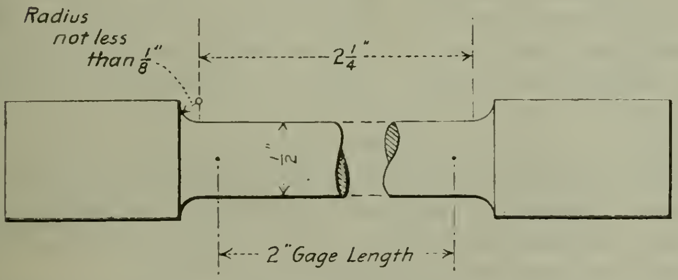


FIG. 1.



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

Test Specimens. 7. (*a*) Two test bars of the form and dimensions shown in Fig. 1 shall be an integral part of large castings, or cast separately in the case of small castings to represent a lot or melt and shall be molded in a manner similar to the castings which they represent. If the castings are heat-treated, the test bars representing such castings shall be similarly heat-treated.

(*b*) The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars. Unless otherwise agreed upon, the minimum lot shall be considered as 500 lb.

(*c*) Tension test specimens, turned from the test bar shown in Fig. 1, shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests. 8. (*a*) Two tension tests shall be made from each lot or melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

IV. INSPECTION AND REJECTION.

Inspection. 9. (*a*) Inspection may be made at the manufacturer's works where castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and, if rejected, shall be replaced by the manufacturer free of cost to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

STANDARD SPECIFICATIONS

FOR

BRONZE BEARING METAL IN INGOT FORM.

Serial Designation: B 31 – 21.

These specifications are issued under the fixed designation B 31; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED, 1921.

Material Covered.

1. These specifications cover copper- tin- lead alloys in ingot form, known commercially as "bronze bearing metal," made wholly or partly from scrap materials. Six typical alloys are specified and are designated as Grades Nos. 1 to 6, in accordance with their decreasing copper content as specified in Section 3.

I. MANUFACTURE.

Uniform Quality.

2. The manufacturer shall use care to have each lot of bronze bearing metal as uniform in quality as possible.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 4:

Alloy, Grade No.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, max., per cent.	Phosphorus, per cent.	Sulfur, max., per cent.	Iron, max., per cent.	Antimony, max., per cent.	Aluminum, per cent.	Total Impurities, max., per cent.
1.......	85	10	5	0.25	0.70[a]	0.05	0.25	0.50	none	0.50
2.......	80	10	10	0.50	0.70[a]	0.05	0.25	0.50	none	0.75
3.......	80	10	10	2.00	0.05[b]	0.05	0.25	0.50	none	2.50
4.......	77	8	15	0.50	0.25[b]	0.05	0.25	0.50	none	0.75
5.......	73	7	20	0.50	0.05[b]	0.25	0.25	0.50	none	1.00
6.......	70	5	25	0.50	none	0.25	0.25	0.50	none	1.00

[a] Minimum. [b] Maximum.

Permissible Variations.

4. The following permissible variations in the percentages of the desired elements specified in Section 3 will be allowed, but

shall not apply to the maximum percentages of impurities specified:

Percentage of Element Specified.	Permissible Variations Over and Under the Specified Value. Units of Per Cent.
Not over 5 per cent	0.50
Over 5 to 10 per cent, incl	0.75
Over 10 per cent	1.50

Samples for Chemical Analysis.

5. (*a*) Three ingots shall be selected by the inspector to represent 10,000 lb. of ingot or fraction thereof.

(*b*) The samples for chemical analysis may be taken either by sawing, drilling or milling the ingots and shall represent the average cross-section.

(*c*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of steel introduced in taking the sample.

III. MARKING.

Marking.

6. The designating mark of the manufacturer, the proper lot number, and the numerical designation of the grade supplied shall be marked on each ingot for identification.

IV. INSPECTION AND REJECTION.

Inspection.

7. (*a*) Inspection may be made at the manufacturer's works where the ingots are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

8. If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 and 4, all ingots in such lot will be rejected.

V. CLAIMS.

Claims. 9. Claims, to be considered, shall be made in writing within thirty days after receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The shipper shall within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment, as specified in Section 5. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Settlement of Claims. 10. The expense of umpire analysis shall be paid by the loser or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of bronze bearing metal meeting these specifications.

APPENDIX.

The data in the following table do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the bronze bearing metal is to be used.

TABLE SHOWING PHYSICAL PROPERTIES OF BRONZE BEARING METAL ALLOYS.

Alloy, Grade No.	Desired Composition.			Ultimate Tensile Strength, lb. per sq. in.[1]	Elongation, in 2 in., per cent.[1]	Brinell Hardness (500 kg. for 30 sec.).	Shrinkage, in. per ft.	Weight, lb. per cu. in.	Compression, Elastic Limit, lb. per sq. in.[2]
	Copper, per cent.	Tin, per cent.	Lead, per cent.						
1..........	85	10	5	28 000	12.5	60	0.25	0.31	18 000
2..........	80	10	10	25 000	8	55	0.25	0.31	15 000
3..........	80	10	10	22 000	8	50	0.25	0.32	12 500
4.......	77	8	15	20 000	10	48	0.25	0.33	12 000
5[a]..	73	7	20	18 000	7	45	0.25	0.33	11 000
6[a]....	70	5	25	15 000	5	40	0.25	0.33	10 000

[a] More difficult to handle in the foundry than the other grades on account of the segregation of lead. Can be improved by the addition of 1 per cent of nickel.

[1] The tension tests were made on "sand cast-to-size" test specimens.

[2] The compression tests were made on machined test specimens (sand castings) of 1 sq. in. sectional area, 1 in. high. The elastic limit is taken as the load producing a compression in the specimen of 0.001 in.

At the request of Committee B-2 on Non-Ferrous Metals and Alloys, Committee E-1 on Methods of Testing is undertaking the revision of the values in this column, on the basis of cylindrical specimens 1 sq. in. in sectional area and 3 in. high. A revision of the methods of determining compression elastic limit is also under consideration.

STANDARD SPECIFICATIONS
FOR
BRONZE BEARING METALS FOR TURNTABLES AND MOVABLE RAILROAD BRIDGES.

Serial Designation: B 22 - 21.

These specifications are issued under the fixed designation B 22; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1918; Adopted, 1921.

Material Covered. 1. (*a*) These specifications cover four classes of bronze bearing metals for turntables and movable railroad bridges.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for contact with hardened steel disks under pressures over 1500 lb. per sq. in., for example, bearing metals, used in turntables and center-bearing swing bridges;

Class B, for contact with soft steel at low speeds under pressures not over 1500 lb. per sq. in., for example, trunnions and journals of bascule and lift bridges;

Class C, for ordinary machinery bearings;

Class D, for gears, worm wheels, nuts and similar parts which are subjected to other than compressive stresses.

I. MANUFACTURE.

Process. 2. (*a*) The bronze shall be a homogeneous alloy of copper and tin. The copper shall conform to the requirements of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 5), or the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars, "high-resistance" grade (Serial Designation: B 4), of the American Society for Testing Materials. The bronze shall be made from new metal, except that scrap of known composition produced by the foundry at which the bronze is cast may be used.

(*b*) Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The bronze shall conform to the following requirements as to chemical composition:

ELEMENTS CONSIDERED.	CLASS.			
	A	B	C	D
Copper, per cent	Remainder	Remainder	not over 82	not over 89
Tin, max., per cent	20	17	11	11
Lead, max., per cent	....	....	11	....
Zinc, max., per cent	....	....	....	2.25
Iron, max., per cent	....	....	....	0.2
Phosphorus, per cent	not over 1.0	not over 1.0	0.7 – 1.0	not over 0.25
Other elements, max., per cent	0.5	0.5	0.5	0.5

Chemical Analyse

4. (*a*) An analysis of each melt may be made at the option of the purchaser and at the purchaser's expense. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.[1]

(*b*) The compression test coupon shall be used for analysis.

III. PHYSICAL PROPERTIES AND TESTS.

Compression and Tension Tests.

5. (*a*) The bronze shall conform to the following requirements as to compressive and tensile properties:

PROPERTIES CONSIDERED.	CLASS.			
	A	B	C	D
COMPRESSION.				
Deformation limit, min., lb. per sq. in.	24 000	18 000	....	....
Permanent set in 1 in. under 100 000 lb. per sq. in., in	0.06 – 0.12	0.10 – 0.20	....	....
TENSION.				
Yield point, min., lb. per sq. in	....	....	....	To be recorded
Tensile strength, min., lb. per sq. in	....	....	....	33 000
Elongation in 2 in., min., per cent	....	....	....	14

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[1] Material with a range of composition differing from that specified in Section 3, or containing elements not specified, may be used, provided the manufacturer shall submit in writing previous to the execution of the contract the range of composition of the material he proposes to use, and provided this range of composition shall be accepted by the purchaser.

(*b*) The deformation limit in compression shall be determined as that load which produces a permanent set of 0.001 in. in the compression test specimen described in Section 6 (*b*).[1]

(*c*) The yield point in tension shall be determined as the stress producing an elongation under load of 0.5 per cent, that is, 0.01 in. in a gage length of 2 in.

Test Specimens. 6. (*a*) A test bar of the form and dimensions shown in Fig. 1, to be used for the tension test specimen, and a suitable

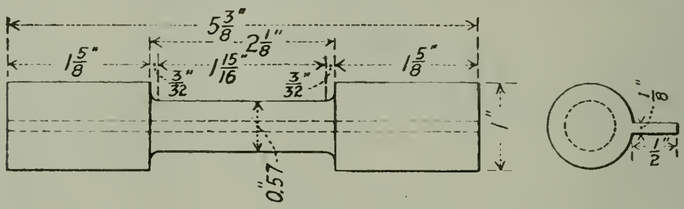
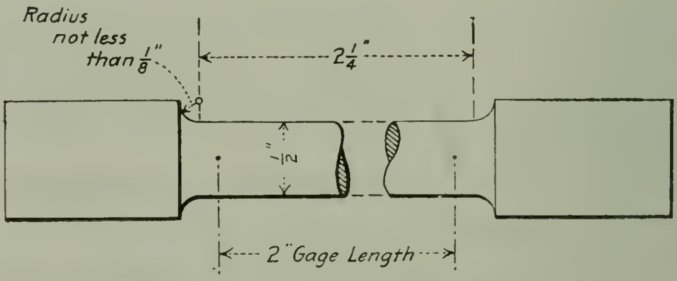


FIG. 1.



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

test bar for the compression test specimen, shall be an integral part of the casting, and shall be fed and cooled under the same conditions as the castings.

(*b*) Compression test specimens shall be cylinders 1 sq. in. in cross-sectional area and 1 in. high.[1]

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[1] The matters of revising the dimensions of compression test specimens and the method of determining the so-called "deformation limit" are under consideration by Committee E-1 on Methods of Testing (see footnote (2) to table on page 429). Tests are being made on cylindrical specimens 1 sq. in. in cross-sectional area and 3 in. high. Committee B-2 on Non-Ferrous Metals and Alloys which has written these specifications feels that these specifications with the present compression tests as specified may be satisfactorily used until better compression test specimens are available.—ED.

(*c*) Tension test specimens, turned from the test bar shown in Fig. 1, shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests

7. (*a*) One compression test shall be made from each melt for Class A and B castings; and one tension test from each melt for Class D castings. For castings of any grade weighing over 100 lb. finished, the specified tests shall be made for each casting.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

IV. FINISH.

Finish.

8. The castings shall be sound, clean, and free from blowholes, porous places, cracks and other defects.

V. INSPECTION AND REJECTION.

Inspection.

9. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

10. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected, shall be replaced by the manufacturer free of cost to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

STANDARD SPECIFICATIONS
FOR
SOLDER METAL.

Serial Designation: B 32 – 21.

These specifications are issued under the fixed designation B 32; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Proposed as Tentative, 1919; Adopted, 1921.

Material Covered. 1. (*a*) These specifications cover lead-tin alloys used for solder metal and commercially known as soft solder.

(*b*) Two classes, A and B, are given, in each of which several compositions are specified covering the range of alloys commercially used and designated as Grades Nos. 0 to 5, in accordance with their decreasing tin content as specified in Section 4.

The choice of the class and grade of solder for any specified purpose depends on the material in connection with which it is to be used and the method of applying. For galvanized iron and zinc, only Class A should be used. Recommended practice is given in an appendix to these specifications, together with a table showing melting points to constitute a guide to the purchaser in selecting the grade best suited for meeting the conditions required.

I. MANUFACTURE.

Uniform Quality. 2. The manufacturer shall use care to have each lot of solder metal as uniform in quality as possible. Each bar, ingot, or other form in which the solder is sold shall be uniform in composition with the entire lot. All grades in Class A shall be made from new or virgin metals. All grades in Class B shall be made from at least one-half new or virgin metals, the balance being recovered or secondary metals.

Dimensions. 3. When specified in bar or ingot form, the sizes or shapes, unless otherwise specified, shall be approximately as follows:

			Length, in.	Width, in.	Thickness, in.
A	Bar	Top	13½	¾	⅝
		Bottom	13½	⅝	
B	Ingot	Top	5½	2½	1½
		Bottom	4½	1½	

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

4. The alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 5:

Grade No.	Tin, per cent.	Lead, Approx., per cent.	Antimony, max., per cent.	Copper, max., per cent.	Zinc and Aluminum, per cent.	Other Impurities,[1] max., per cent.
CLASS A.						
0	63.00	37.00	0.12	0.08	none	0.10
1	50.00	50.00	0.12	0.08	none	0.10
2	45.00	55.00	0.12	0.08	none	0.10
3	40.00	60.00	0.12	0.08	none	0.10
4	37.50	62.50	0.12	0.08	none	0.10
5	33.00	67.00	0.12	0.08	none	0.10
CLASS B.						
1	49.25	50.00	0.75	0.15	none	0.10
2	43.50	55.00	1.50	0.15	none	0.10
3	38.00	60.00	2.00	0.15	none	0.10
4	35.50	62.50	2.00	0.15	none	0.10
5	31.00	67.00	2.00	0.15	none	0.10

[1] Exclusive of Bismuth.

Permissible Variations.

5. The permissible variation plus or minus in the percentage of tin shall not be over 1 per cent of the tin contents specified in Section 4.

Sample for Chemical Analysis.

6. (*a*) Three bars or ingots shall be selected to represent a shipment of less than 1000 lb., five bars or ingots to represent a shipment of over 1000 lb. to 10,000 lb., inclusive, and ten bars or ingots to represent a shipment of over 10,000 lb. to one carload. In case the shipment is in other form, such as wire, wire segments, drops, pigs or slabs, an equivalent amount of metal representative of the lot shall be taken, but in no case shall less than one whole piece (except wire) represent a shipment.

(*b*) The preferable method of preparing the sample for chemical analysis is to cut exactly in half the bars selected, marking each half and retaining one of each of the half bars to preserve their identity and for check analysis. The remaining half of each bar shall then be remelted in a perfectly clean utensil at a temperature a little above the complete liquation point of the alloy, mixed thoroughly and poured into a cold mold, forming a thin bar approximately $\frac{1}{4}$ in. thick. Saw cuts shall then be made entirely across this bar not more than 1 in. apart and evenly distributed throughout its length.

If it is impracticable to remelt the sample as above, saw cuts shall be made entirely across each piece at several points not more than 1 in. apart and evenly distributed throughout their length. No lubricants shall be used for sawing.

(*c*) Sawings thoroughly mixed shall constitute the sample for chemical analysis.

Methods of Chemical Analysis.

7. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper (Serial Designation: B 18) of the American Society for Testing Materials.

III. MARKING.

Marking.

8. The name of the manufacturer may be cast, at the option of the purchaser, on each bar or ingot. The numerical designation of the grade supplied shall be stamped or cast on each bar or ingot for identification.

IV. INSPECTION AND REJECTION.

Inspection.

9. (*a*) Inspection may be made at the manufacturer's works where the solder metal is made, or at the point at which it is received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

10. If the sample selected to represent a lot fails to conform to the requirements specified in Sections 3 and 4, all solder metal in such lot will be rejected.

V. CLAIMS.

Claims.

11. Claims, to be considered, shall be made in writing within thirty days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The shipper

shall within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment, as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Settlement of Claims.

12. The expense of umpire analysis shall be paid by the loser, or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of solder metal meeting these specifications.

APPENDIX.

It is recommended that the grade of solder metal be selected which contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

A table is given showing the melting points of the different grades of solder metal and of tin and lead for comparison. It is to be noted that the alloys are completely solid below the lower point given, designated "melting point", and completely

TABLE SHOWING MELTING POINTS OF SOLDER METAL.

Grade.	Formula.			Melting Point.		Complete Liquation Point.	
	Tin, per cent.	Lead, per cent.	Antimony, per cent.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.
Tin	100.00	......	......	232	449.6	232	449.6
0 A	63.00	37.00	0.12	181	357.8	181	357.8
1 A	50.00	50.00	0.12	181	357.8	213	415.4
1 B	49.25	50.00	0.75	185	365.0	208	397.4
2 A	45.00	55.00	0.12	181	357.8	225	437.0
2 B	43.50	55.00	1.50	188	370.4	220	428.0
3 A	40.00	60.00	0.12	181	357.8	237	458.6
3 B	38.00	60.00	2.00	188	370.4	228	442.4
4 A	37.50	62.50	0.12	181	357.8	241	467.6
4 B	35.50	62.50	2.00	188	370.4	231	411.8
5 A	33.00	67.00	0.12	181	357.8	252	485.6
5 B	31.00	67.00	2.00	188	370.4	235	455.0
Lead	......	100.00	......	327	620.6	327	620.6

liquid only above the higher point given, designated "complete liquation point." In the range of temperature between these two points the alloys are partly solid and partly liquid. In Grade No. 1 the amount of solid portion is so small in the range given that it is practically unnoticeable. In Grade No. 4 the proportion of solid and fluid metal in the range given makes this alloy suitable for use as wiping solder.

The data in this appendix do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the solder metal is to be used.

STANDARD SPECIFICATIONS
FOR
COPPER PLATES FOR LOCOMOTIVE FIREBOXES.

Serial Designation: B 11 – 18.

These specifications are issued under the fixed designation B 11; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1916; ADOPTED, 1918.

Material Covered. 1. These specifications cover two grades of copper for locomotive fireboxes, namely, Arsenical and Non-Arsenical.

I. MANUFACTURE.

Process. 2. The copper shall be fire-refined or electrolytic, and hot rolled from suitable cakes.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The copper shall conform to the following requirements as to chemical composition:

(*a*) *Arsenical Copper.*—Arsenical copper shall contain 0.25 to 0.50 per cent of arsenic, and shall not contain more than 0.120 per cent of impurities, exclusive of arsenic and silver.

(*b*) *Non-Arsenical Copper.*—Non-Arsenical copper shall have a purity of at least 99.880 per cent, as determined by electrolytic assay, silver being counted as copper. The total of impurities other than silver shall not exceed 0.120 per cent.

Chemical Analyses. 4. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 5. The material shall conform to the following minimum requirements as to tensile properties:

	ARSENICAL.	NON-ARSENICAL.
Tensile strength, lb. per sq. in............	31 000	30 000
Elongation in 8 in., per cent..............	35	30

Bend Tests. 6. The specimen shall bend both hot (500 to 700° C.) and cold 180 deg. without cracking on the outside of the bent portion as follows: For material 1 in. or under in thickness, flat on itself; and for material over 1 in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen.

Test Specimens. 7. Tension and bend test specimens shall be taken from the finished rolled material. They shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

Number of Tests. 8. (*a*) One tension, one cold-bend and one hot-bend test shall be made from each plate as rolled.

(*b*) If any test specimen develops flaws it may be discarded and two other specimens substituted, each of which shall be free from flaws. If flaws appear in either or both of the substituted specimens the lot shall be rejected.

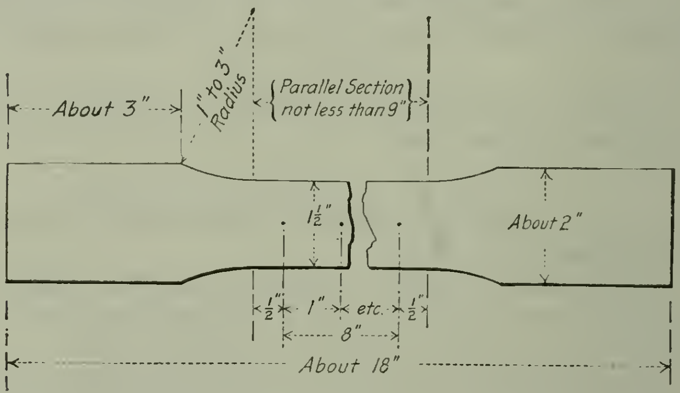


FIG. 1.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(*d*) If any test specimen shows defective machining it may be discarded and another specimen substituted.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Dimensional Variations. 9. The thickness of each plate shall not vary more than 0.04 in. under that ordered. An excess over the nominal weight corresponding to the dimensions on the order shall be allowed for each plate if not more than that shown in Table I. One cubic inch of rolled copper is assumed to weigh 0.323 lb.

V. FINISH.

Finish. 10. The finished plates shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 11. The name or brand of the manufacturer, plate number, and grade shall be stamped on each plate. The plate number shall be legibly stamped on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection. 12. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the plates are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	WEIGHT, LB. PER SQ. FT.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN. Expressed in Percentages of Nominal Weights.			
		Under 75 in.	75 to 100 in., excl.	100 to 115 in., excl.	115 in. or over.
$\frac{5}{16}$	14.53	8	12	16	..
$\frac{3}{8}$	17.44	7	10	13	17
$\frac{7}{16}$	20.34	6	8	10	13
$\frac{1}{2}$	23.25	5	7	9	12
$\frac{9}{16}$	26.16	5	6.5	8.5	11
$\frac{5}{8}$	29.06	5	6	8	10
Over $\frac{5}{8}$	.....	5	5	6.5	9

Rejection. 13. (*a*) Unless otherwise specified, any rejection based on chemical and physical tests made in accordance with these specifications shall be reported within five working days from the receipt of samples.

(*b*) Plates which, subsequent to their acceptance at the manufacturer's works, are shown to have contained injurious defects will be rejected, and the manufacturer shall be notified.

Rehearing. 14. Samples tested in accordance with Section 4, which represent rejected plates, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
COPPER BARS FOR LOCOMOTIVE STAYBOLTS.

Serial Designation: B 12 – 21.

These specifications are issued under the fixed designation B 12; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1916; ADOPTED, 1918; REVISED 1921.

Material Covered. 1. These specifications cover two grades of copper for locomotive staybolts, namely, Arsenical and Non-Arsenical.

I. MANUFACTURE.

Process. 2. The copper shall be fire-refined or electrolytic and shall be finished to dimensions by hot rolling from suitable bars.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The copper shall conform to the following requirements as to chemical composition:

(*a*) *Arsenical Copper.*—Arsenical copper shall contain 0.25 to 0.50 per cent of arsenic, and shall contain not more than 0.120 per cent of impurities, exclusive of arsenic and silver.

(*b*) *Non-Arsenical Copper.*—Non-Arsenical copper shall have a purity of at least 99.880 per cent, as determined by electrolytic assay, silver being counted as copper. The total of impurities other than silver shall not exceed 0.120 per cent.

Chemical Analyses. 4. An analysis may be made from one sample for each 5000 lb. or fraction thereof of finished bars. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 5. The material shall conform to the following minimum requirements as to tensile properties:

	ARSENICAL.	NON-ARSENICAL.
Tensile strength, lb. per sq. in.	31 000	30 000
Elongation in 8 in., per cent	35	30

6. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion. **Bend Tests.**

7. Tension and bend test specimens shall be of the full-size section of the bars as rolled. **Test Specimens.**

8. (*a*) One tension and one bend test shall be made from each 5000 lb. or fraction thereof. **Number of Tests**

(*b*) If any test specimen develops flaws it may be discarded and two other specimens substituted, each of which shall be free from flaws. If flaws appear in either or both of the substituted specimens the lot shall be rejected.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 and any part of the fracture is outside the middle third of gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(*d*) If any test specimen shows defective machining it may be discarded and another specimen substituted.

IV. PERMISSIBLE VARIATIONS IN DIAMETER.

9. The bars shall be truly round within 0.01 in., and shall not vary more than 0.01 in. over nor more than 0.005 in. under the specified size. **Dimensional Variations.**

V. WORKMANSHIP AND FINISH.

10. The finished bars shall be free from injurious defects and shall have a workmanlike finish. **Finish.**

VI. MARKING.

11. The finished bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the lot number for identification. The lot number shall be legibly marked on each test specimen. **Marking.**

VII. INSPECTION AND REJECTION.

12. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

13. (*a*) Unless otherwise specified, any rejection based on chemical or physical tests made in accordance with these **Rejection.**

specifications shall be reported within five working days from the receipt of samples.

(*b*) Bars which, subsequent to their acceptance at the manufacturer's works, are shown to have contained injurious defects will be rejected, and the manufacturer shall be notified.

Rehearing. 14. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
SEAMLESS COPPER BOILER TUBES.

Serial Designation: B 13 – 18.

These specifications are issued under the fixed designation B 13; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1916; Adopted, 1918.

Material Covered.

1. These specifications cover two grades of copper tubes for locomotive boilers, namely, Arsenical and Non-Arsenical.

I. MANUFACTURE.

Process.

2. The copper shall be fire-refined or electrolytic and shall be made into tubes, either by the hot-rolling or cold-drawing process. It shall be finished by cold drawing.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The copper shall conform to the following requirements as to chemical composition:

(*a*) *Arsenical Copper.*—Arsenical copper shall contain from 0.15 to 0.35 per cent of arsenic, and shall not contain more than 0.120 per cent of impurities, exclusive of arsenic and silver.

(*b*) *Non-Arsenical Copper.*—Non-Arsenical copper shall have a purity of at least 99.880 per cent, as determined by electrolytic assay, silver being counted as copper. The total of impurities other than silver shall not exceed 0.120 per cent.

Chemical Analyses

4. (*a*) Analyses of two tubes in each lot of 250 or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analyses shall be taken from several points around each tube, or turnings may be taken from the end of the tube.

(*b*) If the analysis of any one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

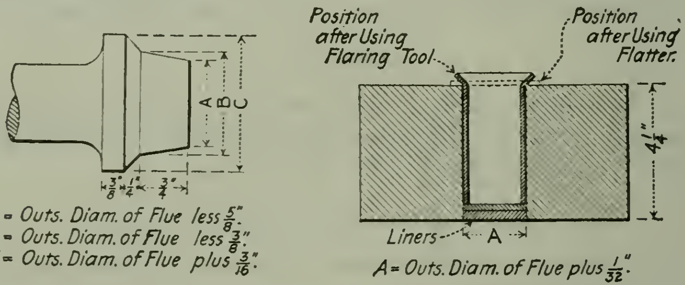
III. PHYSICAL PROPERTIES AND TESTS.

Temper. 5. Tubes will be furnished hard or annealed, as specified. Test specimens taken from hard tubes shall be annealed before testing.

Flange Tests. 6. (*a*) A test specimen not more than 4 in. in length shall have a flange turned over at right angles to the body of the tube, without showing cracks or flaws. This flange, as measured from the outside of the tube, shall be ⅜ in. wide for tubes 2½ in. or under in outside diameter, and ½ in. wide for tubes over 2½ in. in outside diameter.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Crush Tests. 7. A test specimen 2½ in. in length shall stand crushing longitudinally until the outside folds are in contact, without showing cracks or flaws.


A
B
C
3/8"
1/4"
3/4"
A = Outs. Diam. of Flue less 5/8"
B = Outs. Diam. of Flue less 3/8"
C = Outs. Diam. of Flue plus 3/16"
Position after Using Flaring Tool
Position after Using Flatter.
4¼"
Liners
A
A = Outs. Diam. of Flue plus 1/32"

Flaring Tool. Die Block.

Fig. 1.

Hydrostatic Tests. 8. All tubes shall stand an internal hydrostatic pressure of 750 lb. per sq. in. The hydrostatic pressure test shall be applied to the finished tubes before annealing.

Test Specimens. 9. (*a*) Test specimens shall consist of sections cut from tubes selected by the inspector representing the purchaser from the lot offered for shipment. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests. 10. One flange and one crush test shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

11. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

IV. STANDARD WEIGHTS.

Standard Weights. 12. The standards weights for tubes of various outside diameters and thicknesses are as follows:

Thickness.		Weight, lb. per ft. of Length. Outside Diameter, in.				
B. w. g.	In.	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
13	0.095	1.624	1.913	2.202	2.491	2.779
12	0.109	1.844	2.176	2.507	2.839	3.170
11	0.120	2.015	2.380	2.744	3.109	3.474
10	0.134	2.227	2.634	3.042	3.449	3.857
9	0.148	2.434	2.884	3.334	3.785	4.235

Permissible Variations. 13. The weight of the tubes shall not vary more than 5 per cent from that specified in Section 12.

V. WORKMANSHIP AND FINISH.

Workmanship. 14. (*a*) The finished tubes shall be circular within 0.02 in., and the mean outside diameter shall not vary more than 0.015 in. from the size ordered.

(*b*) The thickness at any point shall not vary more than 10 per cent from that specified.

(*c*) The length shall not be less, but may be 0.125 in. more than that ordered.

Finish. 15. The finished tubes shall be free from injurious defects and distortion and shall have a workmanlike finish.

VI. MARKING.

Marking. 16. The name or brand of the manufacturer, and "tested at 750 lb." shall be legibly stenciled on each tube.

VII. INSPECTION AND REJECTION.

Inspection. 17. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 18. (*a*) Unless otherwise specified, any rejection based on chemical or physical tests made in accordance with these specifications shall be reported within five working days from the receipt of samples.

(*b*) Tubes when inserted in the boiler shall stand expanding and bending without showing cracks or flaws. Tubes which fail in this manner will be rejected, and the manufacturer shall be notified.

Rehearing. 19. Samples tested in accordance with Section 4, which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
SEAMLESS BRASS BOILER TUBES.

Serial Designation: B 14 – 18.

These specifications are issued under the fixed designation B 14; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1916; ADOPTED, 1918.

Material Covered. 1. These specifications cover brass tubes for locomotive boilers.

I. MANUFACTURE.

Process. 2. The tubes shall be cold drawn to size and semi-annealed. They shall be fully annealed at both ends, if so ordered.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The material shall conform to the following requirements as to chemical composition:

70–30 ALLOY.

Copper	not under	69.00	per cent
Lead	not over	0.50	"
Iron	" "	0.10	"
Materials other than copper and zinc.	" "	0.50	"
Zinc	remainder		

Chemical Analyses. 4. (*a*) Analyses of two tubes in each lot of 250 or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings or turnings for analyses may be taken from the end of the tube.

(*b*) If the analysis of any one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

III. PHYSICAL PROPERTIES AND TESTS.

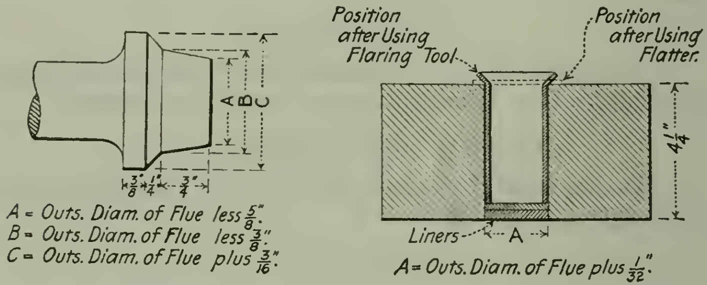
Temper. 5. Test specimens taken from semi-annealed tubes shall be fully annealed before testing.

Flange Test. 6. (*a*) A test specimen not more than 4 in. in length shall have a flange turned over at right angles to the body of the tube without showing cracks or flaws. The outside diameter of this flange shall measure not less than 1¼ times the original outside diameter of the tube.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Flattening and Doubling-Over Test. 7. The tubes shall be capable of standing the following test, when cold, without showing cracks or flaws: A piece of the tube shall be flattened down, until the interior surfaces of the tube meet, and then be doubled over on itself, that is, bent through an angle of 180 deg., the bend being at right angles to the direction of the length of the tube.

Hydrostatic Tests. 8. All tubes shall stand an internal hydrostatic pressure of 750 lb. per sq. in.


A
B
C
3/8"
1/4"
3/4"
A = Outs. Diam. of Flue less 5/8"
B = Outs. Diam. of Flue less 3/8"
C = Outs. Diam. of Flue plus 3/16"
Position after Using Flaring Tool
Position after Using Flatter.
4 1/4"
Liners
A
A = Outs. Diam. of Flue plus 1/32"

Flaring Tool.

Die Block.

FIG. 1.

Test Specimens. 9. (*a*) Test specimens shall consist of sections cut from tubes selected by the inspector representing the purchaser from the lot offered for shipment. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests. 10. One flange and one flattening test shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

Retests. 11. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

IV. STANDARD WEIGHTS.

Standard Weights. 12. The standard weights for tubes of various outside diameters and thicknesses are as follows:

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.				
B. w. g.	In.	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
13	0.095	1.551	1.827	2.102	2.378	2.654
12	0.109	1.761	2.078	2.395	2.711	3.028
11	0.120	1.924	2.272	2.621	2.969	3.318
10	0.134	2.127	2.516	2.905	3.294	3.683
7	0.148	2.325	2.755	3.184	3.614	4.044

Permissible Variations.

13. The weight of the tubes shall not vary more than 5 per cent from that specified in Section 12.

V. WORKMANSHIP AND FINISH.

Workmanship.

14. (*a*) The finished tubes shall be circular within 0.02 in., and the mean outside diameter shall not vary more than 0.015 in. from the size ordered.

(*b*) The thickness at any point shall not vary more than 10 per cent from that specified.

(*c*) The length shall not be less, but may be 0.125 in. more than that ordered.

Finish.

15. The finished tubes shall be free from injurious defects and distortion, and shall have a workmanlike finish.

VI. MARKING.

Marking.

16. The name or brand of the manufacturer, and "tested at 750 lb." shall be legibly stenciled on each tube.

VII. INSPECTION AND REJECTION.

Inspection.

17. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

18. (*a*) Unless otherwise specified, any rejection based on chemical and physical tests made in accordance with these specifications shall be reported within five working days from the receipt of samples.

(*b*) Tubes when inserted in the boiler shall stand expanding and bending without showing cracks or flaws. Tubes which fail in this manner will be rejected, and the manufacturer shall be notified.

Rehearing. 19. Samples tested in accordance with Section 4, which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
BRASS FORGING ROD.

Serial Designation: B 15 – 18.

These specifications are issued under the fixed designation B 15; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1917; ADOPTED, 1918.

Material Covered. 1. These specifications cover brass rods of any specified cross-section capable of being readily forged hot, and easily machined.

I. MANUFACTURE.

Process. 2. The rods may be manufactured either by hot rolling or extrusion, and may be finished by cold drawing if necessary to meet the requirement for size.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The brass shall conform to the following requirements as to chemical composition:

Copper	58.5 – 61.5	per cent.
Lead	1.5 – 2.5	"
Iron	not over 0.15	"
Materials other than copper, lead and zinc	" " 0.35	"
Zinc	remainder.	

Chemical Analyses. 4. Analyses may be made on each lot of 5000 lb. or less. Drillings or millings shall be made from at least four separate rods, equal quantities being taken from each rod and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

Check Analyses. 5. (*a*) Analyses of separate rods may be made by the purchaser. The copper and lead contents thus determined shall lie within the following limits:

Copper	57.9 – 62.1	per cent.
Lead	1.2 – 3.0	"

(*b*) In case of dissatisfaction, the rod or rods shall be sampled in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

III. PHYSICAL PROPERTIES AND TESTS.

Flattening Tests.

6. Specimens cut from rods or bars and having a length equal to the diameter of the specimen, shall stand flattening in an axial direction while hot, until reduced to 20 per cent of their original length, without cracking.

Number of Tests.

7. (*a*) One flattening test shall be made from each lot of 2000 lb. or fraction thereof.

(*b*) In case of failure of any test specimen representing a lot, two additional specimens shall be chosen, each of which shall conform to the requirement specified in Section 6.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Dimensional Variations.

8. (*a*) The diameter of round sections, or the distance between parallel faces in the case of other sections, shall not vary from that specified more than the following:

Diameter, or Distance between Parallel Faces.	Permissible Variation, in.
Up to ½ in., incl.	±0.005
Over ½ to 1 in., incl.	±0.008
Over 1 to 2½ in., incl.	±0.010
Over 2½ in.	±0.015

(*b*) In the case of special shapes, the permissible variations shall be agreed upon according to the requirements.

Lengths.

9. Stock lengths for all rods from ¼ to 1 in., inclusive, in diameter or thickness shall be supplied by the manufacturer as follows:

(*a*) When ordered in 12-ft. lengths, no lengths less than 8 ft.; when ordered in 10-ft. lengths, no lengths less than 6 ft.; when ordered in 8-ft. lengths, no lengths less than 6 ft.; when ordered in 6-ft. lengths, no lengths less than 4 ft.

(*b*) When ordered in the lengths given above, the weight of lengths less than the length ordered shall not exceed 40 per cent of any one shipment.

(*c*) For rods over 1 in. up to and including 2 in. in diameter or thickness, the lengths shall be random lengths from 4 to 10 ft.; for rods over 2 in. in diameter or thickness, special lengths are required, but no length shall be less than 4 ft.

V. WORKMANSHIP AND FINISH.

Finish. 10. The rods shall be free from injurious surface defects and shall have a workmanlike finish. They shall be substantially straight.

VI. INSPECTION AND REJECTION.

Inspection. 11. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

Explanatory Note.

Section 1.—The material intended to be covered by these specifications exhibits a very considerable variation in properties with slight changes in composition. Its strength, stiffness and ability to stand forging operations are in inverse proportion to the copper content; so also is the amount of lead which the alloy can contain without producing hot shortness. Toughness on the other hand is directly proportional to the copper content.

STANDARD SPECIFICATIONS
FOR
FREE-CUTTING BRASS ROD FOR USE IN SCREW MACHINES.

Serial Designation: B 16 – 18.

These specifications are issued under the fixed designation B 16; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1917; ADOPTED, 1918

Material Covered. 1. These specifications cover free-cutting brass rods of any specified cross-section, suitable for high-speed screw machine work.

I. MANUFACTURE.

Process. 2. The rods shall be finished by cold drawing and straightening, unless otherwise specified.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The brass shall conform to the following requirements as to chemical composition:

Copper	60.0 – 63.0 per cent
Lead	2.25 – 3.25 "
Iron	not over 0.15 "
Materials other than copper, lead and zinc	" " 0.25 "
Zinc	remainder.

Chemical Analyses. 4. Analyses may be made on each lot of 5000 lb. or less. Drillings or millings shall be made from at least four separate rods, equal quantities being taken from each rod and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

Check Analyses. 5. (*a*) Analyses of separate rods may be made by the purchaser. The copper and lead contents thus determined shall lie within the following limits:

Copper	59.4 – 63.6 per cent.
Lead	1.8 – 3.9 "

(*b*) In case of dissatisfaction, the rod or rods shall be sampled in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

III. PHYSICAL PROPERTIES AND TESTS.

Bend Tests. 6. Rods or bars shall bend cold through an angle of 120 deg. around a pin the diameter of which is equal to twice the diameter or thickness of the rod or bar, without fracture.

Number of Tests. 7. (*a*) One bend test shall be made from each lot of 5000 lb. or fraction thereof.

(*b*) In case of failure of any test specimen representing a lot, two additional specimens shall be chosen, each of which shall conform to the requirement specified in Section 6.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Dimensional Variations. 8. The diameter of round sections, or the distance between parallel faces in the case of other sections, shall not vary from that specified more than the following:

Diameter, or Distance between Parallel Faces.	Permissible Variation, in.
Up to ½ in. incl.	±0.0015
Over ½ to 1 in., incl.	±0.002
Over 1 to 2½ in., incl.	±0.0025
Over 2½ in.	±0.003

Lengths. 9. Stock lengths for all rods from ¼ to 1 in., inclusive, in diameter or thickness shall be supplied by the manufacturer as follows:

(*a*) When ordered in 12-ft. lengths, no lengths less than 8 ft.; when ordered in 10-ft. lengths, no lengths less than 6 ft.; when ordered in 8-ft. lengths, no lengths less than 6 ft.; when ordered in 6-ft. lengths, no lengths less than 4 ft.

(*b*) When ordered in the lengths given above, the weight of lengths less than the length ordered shall not exceed 40 per cent of any one shipment.

(*c*) For rods over 1 in. up to and including 2 in. in diameter or thickness, the lengths shall be random lengths from 4 to 10 ft.; for rods over 2 in. in diameter or thickness, special lengths are required, but no length shall be less than 4 ft.

V. WORKMANSHIP AND FINISH.

Finish. 10. The rods shall be free from injurious defects, substantially straight and free from kinks and bends, and shall have a bright, smooth surface.

VI. INSPECTION AND REJECTION.

Inspection. 11. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTES.

Section 1.—The material intended to be covered by these specifications is suitable for ordinary manufacturing purposes. In order to machine freely it must contain lead, and possess a considerable degree of temper which is obtained by cold working. The former requirement reduces strength and ductility while the latter adds firmness and stiffness.

Section 3.—There are four major constituents encountered in all brass alloys, the control and determination of which present very perplexing problems. They are copper, zinc, lead and iron. The high volatility of zinc, the variations in temperature which occur in the alloying operation, and the variation in the proportion in which it is added to the crucible charge in unalloyed form, causes its proportion in the casting to occasionally fluctuate over wide limits. Except when certain expensive grades of zinc are employed, substantially free from lead, the latter element will also show very considerable variation. Iron is subject to accidental introduction.

On account of the fact that the ordinary crucible charge is only about 200 lb., it is not commercially practicable to determine the four main elements in each cast. On the other hand, the determination by chemical analysis of the constituents of an individual sample from a lot of a given size tells little about the mean values of the proportions, or the extreme variations which exist in the lot. It is proposed, though not as a very satisfactory solution of this problem, to require that a sample composed of four equal portions from four individual pieces be taken to represent the mean composition of a lot, and that individual samples be permitted to vary between wider limits. It is appreciated that this is not a satisfactory solution of the problem, but no better one has been offered.

There are many uses for which alloys outside of the specified limits are perfectly suitable. The limits given, however, represent standard practice. On the other hand, there are special requirements which cannot be most advantageously satisfied by alloys meeting these specifications.

Section 6.—It is desirable that a limit be imposed on the hardness due to cold drawing. It is felt that the bend test proposed accomplishes the purpose as satisfactorily as any other test.

Section 9.—It is not commercially practicable to furnish material of this character to specific lengths without great expense, especially in the larger sizes, on account of the small size of billet employed. It is, therefore, necessary to permit considerable latitude in this respect.

STANDARD SPECIFICATIONS
FOR
CARTRIDGE BRASS.

Serial Designation: B 19 – 19.

These specifications are issued under the fixed designation B 19; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1918; ADOPTED, 1919.

Material Covered. 1. These specifications cover sheet brass for making rifle and other small arms cartridge cases.

I. MANUFACTURE.

Components. 2. The brass shall be made from lake or electrolytic copper, meeting the requirements of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B-4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B-5) of the American Society for Testing Materials, and zinc of Grades Nos. 1 or 2 of the Standard Specifications for Spelter (Serial Designation: B-6) of the American Society for Testing Materials.

Scrap. 3. No scrap shall be used except that arising from the manufacture of brass or cases made from materials complying with the requirements of Section 2.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. The brass shall conform to the following requirements as to chemical composition:

Copper..............................	66.5 – 69.5	per cent
Lead................................	not over 0.07	"
Iron................................	" " 0.05	"
Other materials.....................	" " 0.15	"
Zinc................................	Remainder.	

Chemical Analyses. 5. Analyses may be made on each lot of 50,000 lb. or less. Drillings or millings shall be made from at least ten separate pieces, equal quantities being taken from each and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

Check Analyses 6. (*a*) Analyses of separate pieces may be made by the purchaser. The copper, lead, and iron contents thus determined shall be as follows:

Copper	66.0 - 70.0	per cent
Lead	not over 0.10	"
Iron	" " 0.08	"

(*b*) In case of dissatisfaction, resampling shall be done in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

III. PHYSICAL PROPERTIES AND TESTS.

Hardness Tests. 7. The brass shall be so annealed that the average of ten Brinell hardness readings from a lot will be within the limits of 51 to 65, using a 10-mm. ball and a pressure of 500 kg. No individual test shall exceed the limits of 50 to 69.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Dimensional Variations. 8. A permissible variation of ±0.002 in. from the specified thickness when measured $\frac{1}{2}$ in. from the edge of the strip will be allowed. The width of the strip may vary ±0.010 in.

Lengths. 9. Cartridge metal may be furnished in coils or flat strips as required. When furnished in flat strips, no strip shall be of less length than 60 per cent of that specified. No lot shall contain more than 40 per cent of such short lengths.

V. WORKMANSHIP AND FINISH

Finish. 10. The metal shall be free from injurious external and internal defects of a nature which will interfere with the purpose for which it is intended. It shall be well pickled and free from dirt. Strips shall be substantially straight and flat.

VI. INSPECTION AND REJECTION.

Inspection. 11. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTES.

Section 7.—A comparative study of Brinell hardness and grain size indicates the following relations:

GRAIN SIZE, MM.	EQUIVALENT BRINELL HARDNESS NUMBER.
0.150	47
0.111	49
0.100	49.7
0.098	50
0.087	51
0.075	52¼
0.060	54¾
0.058	55
0.050	57½
0.044	60
0.040	62½
0.034	65
0.030	68
0.029	69

As it is easier and quicker to take the Brinell hardness than to polish and etch samples for study with the microscope, the Brinell hardness is much to be preferred. Furthermore, through straightening or flattening operations, cartridge metal may be hardened to an appreciable extent without affecting the grain size or producing any noticeable distortion.

Many operators in making rapid determinations of grain size slight the polishing and etch in strong acids, so that it is frequently impossible to distinguish between twinned crystals and separate crystals and a false grain count is obtained.

Section 10.—The differentiation between immaterial and injurious defects is a matter which requires a considerable degree of knowledge as to the causes of the various kinds of imperfections which are encountered in material of this character, as well as a thorough understanding of the effects thereof upon its further fabrication and use. In general, two classes may be readily distinguished, namely, those which are imposed and those which are inherent. In the former class are dents and scratches caused by blows or abrasion, and foreign matter which, adhering to the surface of the material, may have been rolled into it. Dents and scratches may be of considerable magnitude and still disappear completely in subsequent operations of fabrication. Similarly the presence of imposed foreign matter may be relatively unimportant. The point to be observed in this connection is that the presence of this class of defects is indicative of nothing beyond their presence.

Inherent defects are those which occur as a result of the presence either of gas or foreign matter included in the material during the process of casting. Metal is seldom entirely free from such defects and visual evidence of these argues the presence of others not visible. Experience is needed to determine whether any such encountered are of a magnitude and character sufficient to establish a departure from correct casting practice sufficient to disqualify the material.

A third character of defect, and one of a grave nature, is caused by failure to completely remove any piping which may have occurred in casting. The indications of this defect are, however, well pronounced and characteristic.

STANDARD SPECIFICATIONS
FOR
CARTRIDGE BRASS DISKS.

Serial Designation: B 20 – 19.

These specifications are issued under the fixed designation B 20; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1918; ADOPTED, 1919.

Material Covered. 1. These specifications cover brass disks for making artillery cartridge cases.

I. MATERIAL.

Metal. 2. The disks shall be made of cartridge brass conforming to the requirements of the Standard Specifications for Cartridge Brass (Serial Designation: B 19) of the American Society for Testing Materials; except as to dimensions and permissible variations thereof, which shall conform to the requirements specified in Section 3.

II. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Dimensional Variations. 3. (*a*) Variations in dimensions shall conform to the following limits:

Diameter.	Permissible Variation, in.	Gage.	Permissible Variation, in.
Up to 1 in., incl.	± 0.0025	Up to 0.150 in., incl.	± 0.0025
Over 1 to 3 in., incl.	± 0.003	Over 0.150 to 0.300 in., incl.	± 0.003
Over 3 to 6 in., incl.	± 0.004	Over 0.300 to 0.400 in., incl.	± 0.004
Over 6 to 8 in., incl.	± 0.005	Over 0.400 in.	± 0.005
Over 8 in.	± 0.0075		

(*b*) The thickness of disks should be measured not less than $\frac{1}{2}$ in. from the edge and on the diameter at right angles to the direction in which the bar was rolled.

STANDARD SPECIFICATIONS
FOR
NAVAL BRASS RODS FOR STRUCTURAL PURPOSES.

Serial Designation: B 21 – 19.

These specifications are issued under the fixed designation B 21; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1918; Adopted, 1919.

Material Covered. 1. These specifications cover naval brass rods of any uniform cross-section such as round, hexagonal, square, etc.

I. MANUFACTURE.

Process. 2. The rods shall be manufactured either by hot rolling or extrusion, finished by such cold drawing as may be required, and straightened.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The brass shall conform to the following requirements as to chemical composition:

Copper	59.00 – 62.00	per cent
Tin	0.50 – 1.50	"
Iron	not over 0.10	"
Lead	" " 0.30	"
Materials other than above	" " 0.10	"
Zinc	Remainder.	

Chemical Analyses. 4. Analyses may be made on each lot of 5000 lb. or less. Drillings or millings shall be made from at least four separate rods, equal quantities being taken from each rod and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

Check Analyses. 5. (*a*) Analyses of separate rods may be made by the purchaser. The copper content thus determined shall lie within the following limits:

Copper	59 – 63 per cent.

(*b*) In case of dissatisfaction, the rod or rods shall be sampled in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. The rods shall conform to the following minimum requirements as to tensile properties:

Diameter, or Distance between Parallel Faces.	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent.
Up to 1 in., incl.	31 000	62 000	25.0
Over 1 to 2½ in., incl.	30 000	60 000	30.0
Over 2½ to 3½ in., incl.	25 000	56 000	35.0
Over 3½ in.	22 000	54 000	40.0

Bend Tests. 7. The test specimen shall bend cold through 120 deg. to a radius equal to its diameter, without fracturing.

Strain Tests. 8. The test specimen shall stand an immersion in a mercurous-nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter for 15 minutes, without fracturing.

Test Specimens. 9. (*a*) Tension test specimens shall be as nearly as possible of the same diameter, or distance between parallel faces, as the rods.

(*b*) Bend test specimens may be a piece of the full size rod, or a piece 1 in. in width by ½ in. in thickness. In the case of bend test specimens of rectangular section, the edges may be rounded off to a radius equal to one-fourth of the thickness.

(*c*) Strain test specimens shall be of the full size of the rod, at least 12 in. long, and without bending, springing, polishing, or any other preparation. At least 9 in. of the length of the specimen shall be immersed in the solution.

Number of Tests. 10. (*a*) Rods shall be grouped into lots of not more than 5000 lb.

(*b*) One tension, one bend, and one strain test specimen shall be cut from one rod for each lot or fraction thereof.

(*c*) If any tension test specimen breaks outside the middle third of the gage length, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Dimensional Variations. 11. The diameter of round sections, or the distance between parallel faces in the case of other sections, shall not vary from that specified more than the following:

Diameter, or Distance between Parallel Faces.	Permissible Variation, in.	
	Rounds.	Other Shapes.
Up to ½ in., incl	± 0.0015	± 0.003
Over ½ to 1 in., incl	± 0.0020	± 0.004
Over 1 to 2½ in., incl	± 0.0025	± 0.005
Over 2½ in	± 0.0030	± 0.006

Lengths. 12. Rods, when ordered to any length, will be received in stock lengths, unless it is specifically stated that the lengths are to be exact. Stock lengths for all rods from ¼ to 1 in., inclusive, in diameter or thickness shall be as follows:

(*a*) When ordered in 12-ft. lengths, no lengths less than 8 ft.; when ordered in 10-ft. lengths, no lengths less than 6 ft.; when ordered in 8-ft. lengths, no lengths less than 6 ft.; when ordered in 6-ft. lengths, no lengths less than 4 ft.

(*b*) When ordered in the lengths given above, the weight of lengths less than the length ordered shall not exceed 40 per cent of any one shipment.

(*c*) For rods over 1 in. up to and including 2 in. in diameter or thickness, the lengths shall be random lengths from 4 to 10 ft.; for rods over 2 in. in diameter or thickness, special lengths are required, but no length shall be less than 4 ft.

V. WORKMANSHIP AND FINISH.

Finish. 13. The rods shall be free from injurious defects, substantially straight and free from kinks and bends, and shall have a bright, smooth surface.

VI. INSPECTION AND REJECTION.

Inspection. 14. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the rods are being furnished in accordance with these specifications.

Rejection. 15. Rods which fail to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTES.

Section 1.—Material intended to be covered by these specifications is suitable for structural purposes, and may be used as rods, bolts, etc. It is capable of being forged hot, but is not free cutting.

Section 5.—Consumers sometimes desire to judge material on the results obtained by a single sample. Due to a variety of causes, the copper content of material of this character is subject to variations of considerable magnitude. Moreover the melting unit is small, or about two or three hundred pounds. To take care of these circumstances, it is necessary to have a wider tolerance for determinations on single samples than is the case where a composition sample is used. It is not necessary to restrict the tin, iron, and lead contents within narrow limits. Consequently the values given in Section 3 need not be changed for an individual sample.

Section 8.—Bars which have been properly straightened or sprung will have internal stresses so broken up as not to be in danger of splitting or cracking. The mercurous-nitrate test is designed to determine whether the internal stresses have been properly broken up and rendered safe.

STANDARD SPECIFICATIONS
FOR
HIGH SHEET BRASS.

Serial Designation: B 36 – 21.

These specifications are issued under the fixed designation B 36; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1920; Adopted, 1921.

Material Covered.

1. These specifications cover commercial sheet brass commonly used for drawing, forming, stamping and bending. It should be understood that they are general. Since high brass is used for many purposes where the requirements of the operations used are too particular to be specified by any of the ordinary physical tests, it is frequently advisable to submit samples or drawings to the manufacturer and secure an adjustment of anneal or temper to suit the actual operations to which the material is to be submitted.

I. MANUFACTURE.

Composition.

2. (*a*) High sheet brass shall be made from Lake or Electrolytic Copper conforming to the requirements of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 5) of the American Society for Testing Materials, and zinc of Grade 3 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials. Clean new scrap resulting from manufacturing operations upon material complying with these specifications or composed of material of equal purity may be employed.

(*b*) The brass shall be manufactured by the cold-rolling and annealing process and may be furnished in either the cold-rolled or annealed condition, as required.

II. CHEMICAL PROPERTIES.

Chemical Composition.

3. The brass shall conform to the following requirements as to chemical composition:

Copper	64.5 to 67.5	per cent
Lead	not over 0.30	"
Iron	" " 0.05	"
Zinc	remainder	
Other impurities	not over 0.10	"

Chemical Analyses.

4. Analysis shall be made on each lot of 10,000 lb. or less. Drillings, millings or clippings shall be taken from at least 10 separate coils or pieces. Drillings or millings shall be taken on material thicker than 0.040 in. Clippings may be taken with shears from metal thinner than 0.040 in. Equal quantities shall be taken from each piece and thoroughly mixed together. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire if necessary.

Check Analyses.

5 (*a*) Analyses of separate pieces may be made by the purchaser. The copper, lead, and iron determined shall be within the following limits:

Copper	64.00 to 68.00	per cent
Lead	not over 0.35	"
Iron	" " 0.07	"

(*b*) In case of dissatisfaction the metal shall be resampled in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each one of which shall be placed in a sealed package, one for each party and one for an umpire if necessary.

III. TEMPER AND ANNEAL.

Temper.

6. The temper of sheet brass shall be designated as follows:

	Reduction, B. & S. Gage Nos.
Quarter Hard	1
Half Hard	2
Hard	4
Extra Hard	6
Spring	8

Anneal.

7. Annealed sheet brass shall be designated as follows:

Light Anneal.
Drawing Anneal.
Soft Drawing Anneal.

IV. PHYSICAL PROPERTIES AND TESTS.

(*A*) *Hard Brass.*

Hardness Tests, Hard Brass.

8. The average Brinell hardness of 10 samples of cold-rolled brass 0.080 in. or over in thickness shall be within the following limits:

Quarter Hard	75 – 95
Half Hard	95 – 115
Hard	130 – 150
Extra Hard	150 – 170
Spring	160 – 180

Tensile Tests, Hard Brass.

9. The average of tension tests of two samples of cold-rolled brass thinner than 0.080 in. shall conform to the following minimum requirements:

	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT.
Quarter Hard	45 000	27.5
Half Hard	52 500	15.0
Hard	67 500	5.0
Extra Hard	80 000	2.0
Spring	87 500	1.0

(*B*) *Soft Brass.*

Hardness Tests, Soft Brass.

10. The average Brinell hardness of ten samples of annealed brass 0.080 in. or over in thickness shall be as follows:

Light Anneal	65 – 75
Drawing Anneal	55 – 65
Soft Drawing Anneal	47 – 55

Tension Tests, Soft Brass.

11. The average of tension tests of two samples of annealed brass thinner than 0.080 in. shall conform to the following minimum requirements:

	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT.
Light Anneal	45 000	32.0
Drawing Anneal	42 000	38.0
Soft Drawing Anneal	40 000	42.0

V. PERMISSIBLE VARIATION IN DIMENSIONS.

Width.

12. The width of sheared metal shall not vary more than 0.010 in.

Thickness.

13. The standard method of specifying thickness shall be in terms of Brown & Sharpe Gage. When the thickness is specified in either common or decimal fractions of an inch, the toler-

ances shall be those of the corresponding group of Brown & Sharpe sizes in the following table:

TABLE I.—PERMISSIBLE VARIATION IN THICKNESS, IN.

Thickness, B. & S. Gage No.	Thickness, in.	Width, in.			
		Up to 5, incl.	Over 5 to 8, incl.	Over 8 to 11, incl.	Over 11 to 14, incl.
0000 to 0, incl.........	0.4600 to 0.3248	±0.0044	±0.0048	±0.0051	±0.0055
Below 0 “ 4, “	0.3248 “ 0.2043	±0.0039	±0.0043	±0.0046	±0.0050
“ 4 “ 8, “	0.2043 “ 0.1284	±0.0034	±0.0038	±0.0041	±0.0045
“ 8 “ 14, “	0.1284 “ 0.0640	±0.0029	±0.0033	±0.0036	±0.0040
“ 14 “ 18, “	0.0640 “ 0.0403	±0.0025	±0.0029	±0.0033	±0.0037
“ 18 “ 24, “	0.0403 “ 0.0201	±0.0020	±0.0024	±0.0028	±0.0032
“ 24 “ 28, “	0.0201 “ 0.0126	±0.0016	±0.0020	±0.0024	±0.0028
“ 28 “ 32, “	0.0126 “ 0.0079	±0.0013	±0.0017	±0.0020	±0.0024
“ 32 “ 35, “	0.0079 “ 0.0056	±0.0010	±0.0014	±0.0017	±0.0022
“ 35 “ 38, “	0.0056 “ 0.0039	±0.0008	±0.0012	±0.0015	±0.0019

Length. 14. Metal may be furnished in coils or flat strips as required. Coils shall consist of not more than three lengths, no one of which shall be less than 10 ft. long. When furnished in flat strips a variation of $\frac{1}{16}$ in. over the specified length will be permitted on full-length sheets.

Acceptable Short Lengths. 15. (*a*) When ordered in lengths over 10 to 12 ft.,

40 per cent may be 10 ft. and over.
30 “ “ “ 8 to 10 ft.
20 “ “ “ 6 to 8 ft.
10 “ “ “ 4 to 6 ft.

Not more than 40 per cent of any one shipment may be less than the length ordered.

(*b*) When ordered in 10 ft. lengths,

40 per cent may be 8 ft. and over.
30 “ “ “ 6 to 8 ft.
20 “ “ “ 4 to 6 ft.
10 “ “ “ 2 to 4 ft.

Not more than 40 per cent of any one shipment may be less than 10 ft.

(*c*) When ordered in 8 ft. lengths,

30 per cent may be 6 ft. and over.
20 “ “ “ 4 to 6 ft.
10 “ “ “ 2 to 4 ft.

Not more than 30 per cent of any one shipment may be less than 8 ft.

(*d*) When ordered in 6 ft. lengths,

20 per cent may be 4 ft. and over.
10 " " " 2 to 4 ft.

Not more than 20 per cent of any one shipment may be less than 6 ft.

(*e*) When special lengths are required, they shall be specified in the order.

VI. WORKMANSHIP AND FINISH.

16. The brass shall be free from injurious external and internal defects of a nature which will interfere with the purpose for which it is intended. It shall be well cleaned and free from dirt. **Finish.**

VII. INSPECTION AND REJECTION.

17. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. **Inspection.**

18. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified. **Rejection.**

EXPLANATORY NOTE.

Section 2.—In the making of brass the best results are obtained if a minimum of one-third of previously alloyed material is used. It is also frequently desirable to employ previously alloyed material composed of copper and zinc in proportions other than provided for in these specifications, sufficient copper and zinc being added as may be required to properly correct the composition.

STANDARD METHODS OF BATTERY ASSAY
OF
COPPER.

Serial Designation: B 34 – 20.

These methods are issued under the fixed designation B 34; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED 1920.

These methods were approved June 15, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

APPROVED BY THE SUPERVISORY COMMITTEE ON STANDARD METHODS OF ANALYSIS, AMERICAN CHEMICAL SOCIETY.

The methods that follow are those originally proposed by Heath,[1] whose work has been checked and elaborated by Keller, Ferguson and others.

The methods are those generally accepted in the United States for standard analysis in all the larger laboratories of both producers and consumers of copper and copper products.

GENERAL INSTRUCTIONS.

Sampling Ingots.—Select six ingots at random from the lot. Considering three ingots as a rectangular unit, drill one hole in each ingot, one at the center and one at each end of a diagonal of the rectangle. Drill each hole entirely through the ingot, starting from the bottom. Start the drill on the surface sufficiently to remove the oxide before commencing to collect the drillings for the sample. Run the drill so as to prevent oxidation of the chips. Discard all drillings carrying oxide from the "set," or burned by the drill. Use no lubricant on the drill, and if the sample shows oil or grease, remove this with ether. Sift all drillings on a screen with 250 meshes per sq. cm. in order to remove material which is ground between the drill and sides of the hole. Extract with a strong magnet any iron which may have come from the drill. Keep the drillings in air-tight bottles.

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[1] Heath, *Transactions*, Am. Inst. Min. Engrs., Vol. 27, pp. 390–400 (1897).

Weights.—Weights shall be calibrated and frequently rechecked. It is recommended[1] to use a special 5-g. brass weight in weighing the samples and to have the weight of the sample always within 5 mg. of 5 g. When the cathode with its deposit is finally weighed the identical weights are to be used with which the cylinder was tared, plus the special 5-g. brass weight. This brings all the change or deficiency in the final weight on a small fractional weight and the beam and rider.

ASSAY OF ELECTROLYTIC AND LOW-RESISTANCE LAKE COPPER.

The method described below is applicable to such grades of electrolytic and low-resistance lake copper as are covered by the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4) and for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5), of the American Society for Testing Materials. The silver is deposited with the copper and is included as such; when it is desired to correct for the silver this is determined in a larger separate sample and the amount found is deducted from the deposit of copper plus silver.

Apparatus for Electrolysis.

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less of the operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and electrically welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

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[1] Greenwood, U. S. Metals Refining Co., Personal Communication.

Anodes.—Spiral platinum anodes should be used, made from 1.02-mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm.

SOLUTION REQUIRED.

"Assay Solution" for Dissolving.—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84), 210 cc. of HNO_3 (sp. gr. 1.42) and 750 cc. of distilled water.

METHOD.

Place 5 g. of the drillings in a tall lipless beaker which is provided with a well-fitting cover glass, and add 42 cc. of "Assay Solution." The electrolysis beakers are from 100–125 mm. tall and 55 mm. in diameter across the bottom, with a total capacity of 225 to 300 cc. After the assays have stood for a few minutes and the action has nearly ceased, place them on a steam bath having a temperature of 80 to 90° C. and allow them to remain there until solution is completed and the red fumes have disappeared. Wash the cover and the sides of the beaker and dilute the solution to 150 cc. and electrolyze, keeping the top of the cathode 5 or 6 mm. below the surface of the solution.

During electrolysis, cover the beakers with two pairs of split watch glasses placed at right angles to each other. For each solution use a current of one ampere at approximately 10 volts, or else use a current of 4 amperes at approximately 10 volts continued for about 4 hours. The latter case requires the use of gauze cathodes. In the former case, it is convenient to start the assays at night; after about 15 hours wash the cover glasses, electrodes and beakers and reduce the current to 0.6 ampere per solution. As soon as the cathodes begin to evolve gas reduce the current to 0.4 ampere per solution. When this occurs take out about 1 cc. of liquid, place it in a depression in a porcelain test plate and add two or three drops of fresh H_2S water. If the slightest discoloration occurs continue the electrolysis, repeating the test until there is no discoloration whatever.[1] If possible the assay should finish without decided evolution of gas.

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[1] It has been shown by Heath, *Journal of Industrial and Engineering Chemistry*, Vol. 4, p. 404 (1912), that a few thousandths of a per cent of copper may remain in the solution without being detected by the test on the spot plate. This amount of copper is negligible in many

Without interrupting the current, siphon off the acid solution, at the same time filling the beakers with distilled water. Remove the cathodes quickly and rinse them in distilled water and two successive baths of alcohol. An experienced operator can quickly remove a cathode and immerse it in water without loss. Throw off the excess alcohol by a quick motion of the hand and ignite the remainder by bringing the cathode quickly to the flame of an alcohol lamp; then keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

Accuracy.—All assays shall be made in duplicate and shall check within an outside limit of 0.015 per cent of copper.

NOTES.

Use of the "Assay Solution" prevents a violent reaction and a consequent loss of copper with the vapors. The solution should not be boiled, since this likewise may cause a loss of copper.

By the use of rotating anodes, gauze or perforated electrodes or the Frary solenoid, it is possible to use a high current density and to reduce the time required for depositing the copper to about four hours. Good results can be obtained by experienced workers, but there is much more chance for error. The slow or over-night method, which is more certain and which requires less of the operator's time, is therefore recommended.

The deposition of the silver with the copper is said to work well up to the limit of 0.3 per cent silver, that is, 100 oz. per ton.

The method of burning off the alcohol in the flame of an alcohol lamp dries the cathode without causing oxidation, whereas drying in an oven to 100° C. generally causes increase in weight.

ASSAY OF LOW-GRADE OR CASTING COPPER.

For all grades of copper which are not included in the specifications of the American Society for Testing Materials, previously referred to, as Electrolytic and Low-Resistance Lake Copper, the procedures given below are recommended. These brands may contain a considerable amount of arsenic and some antimony, tellurium, bismuth and nickel. (See Notes.)

SOLUTION REQUIRED.

"Assay Solution" for Dissolving.—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84), 210 cc. of HNO_3 (sp. gr. 1.42) and 750 cc. of distilled water.

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instances, but when necessary to make exact determinations, as in the complete analysis of copper, make the solution, after electrolysis, slightly alkaline, neutralize with HCl (sp. gr. 1.19), adding 3 cc. excess, evaporate to 50 cc. and precipitate with H_2S. Filter off the copper sulfide, treat with HNO_3 and H_2SO_4, deposit the small amount of copper from the solution by electrolysis and add it to that obtained in the original determination.

METHOD I.

Carry out the assay exactly as given for Electrolytic and Low-Resistance Lake Copper. Place the cathode in a clean beaker, cover with a watch glass perforated with a small hole just large enough to accommodate the stem of the electrode, add 42 cc. of "Assay Solution" and water enough to cover the sheet. Let it stand upon the steam bath until the coating is dissolved. Re-electrolyze in the regular manner.

METHOD II.[1]

Dissolve a 5-g. sample in 42 cc. of the "Assay Solution" and evaporate until all the HNO_3 is expelled. Redissolve in 70 cc. of water and add 3 cc. of ferric nitrate solution (1 cc. = 0.01 g. of iron). Transfer the solution to a lipped beaker and place the original beaker under a funnel fitted with a small filter paper. Precipitate the iron from the hot liquid by ammonia, filter and wash out salts. Place the solution on a hot plate to concentrate, reprecipitate the hydroxide from dilute H_2SO_4 in a very small volume of solution and add the filtrate to the main solution. Reprecipitate the hydroxide once more from dilute H_2SO_4, filter, wash thoroughly and add the filtrate to the main solution. Make acid with dilute H_2SO_4 and add 2 cc. of HNO_3 (sp. gr. 1.42). Deposit the copper as in the method for Electrolytic and Low-Resistance Lake Copper.

METHOD III.[2]

(FOR COPPER CONTAINING ONLY TRACES OF ANTIMONY OR BISMUTH BUT SUFFICIENT SELENIUM OR TELLURIUM TO INTERFERE.)

Dissolve the 5-g. sample in 42 cc. of "Assay Solution" and evaporate until fumes appear, or until the residue is white. Redissolve in 60 cc. of water and saturate the boiling hot solution for 10 minutes with SO_2 gas, removing the solution from the lamp when the gas is started. The gas may be generated by dropping cold saturated sodium sulfite solution into strong H_2SO_4. It is also conveniently obtainable in cylinders which are fitted with a valve. Let the precipitate settle for a few hours, filter and wash with a little hot water. Boil the filtrate gently to remove most of the SO_2 gas. Ignite the filter in a porcelain crucible to volatilize the selenium and tellurium, redissolve the oxidized residue in 1.5 to 2 cc. of HNO_3 and add to the main solution. Deposit the copper as in the method for Electrolytic and Low-Resistance Lake Copper.

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[1] Heath (Senter modified), *Journal* Am. Chem. Soc., Vol. 26, p. 1123 (1904).

[2] Heath, *Ibid.*, Vol. 26 p. 1123 (1904); Keller, *Transactions*, Am. Inst. Min. Engrs., p. 2098 (1913), *Bulletin No. 80*.

NOTE.

The selenium is said to be carried down by SO_2 as a selenide of silver, but the roasting sufficiently removes the elements selenium and tellurium. When silver is to be removed, the selenium, etc., are thrown down with the silver by the SO_2 gas and the precipitation of silver is then completed by the addition of chlorides or HCl.

METHOD IV.[1]

(FOR COPPER HIGH IN ARSENIC ONLY.)

Modification A.—Dissolve the sample in 42 cc. of the "Assay Solution" in the regular way and add 5 g. of ammonium nitrate. Electrolyze as usual.

Modification B.—Dissolve the sample in 60 cc. of the "Assay Solution" instead of 42 cc. Electrolyze as usual.

Accuracy.—All assays shall be made in duplicate and shall check with an outside limit of 0.015 per cent of copper.

NOTES.

It has been recommended[2] to use with solutions of the Low-Grade or Casting Copper about 2 cc. of an addition-agent prepared by boiling "lard oil" with strong HNO_3, cooling and removing the grease. This, it is said, will permit the use of high current densities and yet allow the copper to be deposited pure and bright. Moreover, it is said that arsenic and antimony, when present, do not contaminate the copper. It seems probable,[3] however, that copper deposited from such solutions is not quite pure and that it is more accurate to purify the cathode deposit (Method I) or to give a preliminary treatment to the solution (Method II).

Method II is recommended in preference to Method I, which should be used only in the presence of small amounts of impurities.

In Method IV for copper high in arsenic, *Modification B* is to be preferred.

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[1] *Modification A.*—Heath, *Journal*, Am. Chem. Soc., Vol. 26 p. 1124 (1904); *Modification B.*—Heath, *Journal of Industrial and Engineering Chemistry*, Vol. 3 p. 75 (1911).

[2] Guess, *Transactions*, Am. Inst. Min. Engrs., Vol. 36, p. 605 (1905).

[3] Keller, *Ibid.*, p. 2099 (1913), *Bulletin No. 80*: Heath, *Journal of Industrial and Engineering Chemistry*, Vol. 3, p. 75 (1911).

STANDARD METHODS OF CHEMICAL ANALYSIS OF PIG LEAD.

Serial Designation: B 35 – 20.

These methods are issued under the fixed designation B 35; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1919; Adopted, 1920.

A. DETERMINATION OF SILVER.

Weigh 100 g. of the sample into a 3-in. scorifier and heat in a muffle furnace until the assay "covers." Pour into an iron mold and allow to cool. Free the resulting lead button from PbO, scorify again and pour as before. The button last obtained should not weigh over 20 g. and can be cupelled directly. Weigh the silver button obtained upon an assay balance.

Note.

If the amount of silver is large, the button should be examined for gold, in the usual manner.

B. DETERMINATION OF BISMUTH.

Solutions Required.

Sodium Carbonate.—Dissolve 100 g. Na_2CO_3 in a liter of distilled water.

Ammonium Carbonate.—Make a half saturated solution.

Alkaline Sulfide Wash Solution.—Dissolve 200 g. of KOH in a liter of distilled water and mix one part of this solution with 4 parts of H_2S water.

Method.

(*a*) *Determination for Ordinary Amounts of Bismuth.*

Dissolve 20 g. of the sample in a 400-cc. beaker with 100 cc. of HNO_3 (1 : 4), with the aid of heat. When solution is complete, add dilute ammonia (1 : 2) with constant stirring, drop by drop from a burette, until a faint opalescence appears. If an actual precipitate is formed, redissolve by the addition of a small amount of HNO_3 (1 : 4) and repeat the addition of ammonia. Now add 5 cc. of HCl (1 : 9), fill the beaker with hot water, bring to boiling, and allow to stand on a steam bath for two hours. The assay, while standing, must not reach the boiling temperature. Filter through a 7-cm. paper. Transfer the precipitate completely to the paper by means of a "policeman" and wash twice with hot water. Carefully examine the filtrate, washings, and any decanted liquid and reject if clear. Dissolve the precipitate by dropping around the edges, from a 5-cc. pipette, 5 cc. of boiling HCl (1 : 9), receiving the solution in the original beaker. Wash the paper thoroughly with hot water, fill the beaker with water, bring to boiling, and allow to stand as before. Filter the bismuth oxychloride upon a weighed Gooch crucible, wash thoroughly with water, once with alcohol, once with ether, and dry upon the hot plate. Cool and weigh.

NOTE.

If time permits it is convenient to allow the assay to stand over night. In that case, the precipitate of bismuth oxychloride generally settles so completely that the clear supernatant solution can be decanted.

(b) Determination for Amounts of Bismuth Smaller than Can be Determined by (a).

Dissolve 100 g. of the sample in 500 cc. of dilute HNO_3 (1:4). When solution is complete, allow to cool and add Na_2CO_3 solution little by little until a slight permanent precipitate has formed. Then add 50 cc. of the Na_2CO_3 solution, bring to boiling, allow to stand warm until the supernatant liquor is clear again, filter and reject the filtrate. Dissolve the precipitate without washing by slowly pouring hot HNO_3 (1 : 4) around the edges of the filter paper, using no more acid than necessary. Wash the paper once with hot water and determine bismuth in the filtrate as described in (*a*)

NOTE.

When the sample contains a small amount of bismuth, it is often difficult to ascertain when the correct amount of ammonia has been added to the nitrate solution. In this case, place a small piece of litmus paper in the solution, and add the ammonia very gradually until the litmus paper indicates a neutral reaction.

(c) Determination of Bismuth in Samples Containing Appreciable Amounts of Tin and Antimony.

Use a piece of litmus paper as in Note under (*b*), and after the first precipitation of bismuth oxychloride has been filtered off and washed (see (*a*)) proceed as follows: Dissolve the bismuth by dropping around the edges of the paper 10 cc. of boiling HCl (1 : 2), receiving the solution in the original beaker. Discard the paper after washing. Dilute the solution to about 200 cc. with fresh H_2S water and then pass H_2S gas through the hot solution for 15 minutes. Filter and wash with hot water. Remove any tin or antimony present by washing three times with alkaline sulfide wash solution. Wash the precipitate again with hot water, place it, together with the filter paper, in a 100 cc. beaker, add 20 cc. of HNO_3 (1:4), boil until sulfides are completely dissolved and the paper well pulped. Filter the solution, receiving the filtrate in the original beaker, and wash well. Determine bismuth in the filtrate as in (*a*).

NOTES.

When the sample contains comparatively large amounts of tin or antimony, the residue left after the solution of the lead in the nitric acid obscures the opalescence found upon the addition of ammonia.

If the original sample contains more than 0.25 per cent of bismuth, it is preferable to use only a 10-g. charge.

C. DETERMINATION OF ARSENIC.

METHOD.

Dissolve 111.11 g. of the sample in 550 cc. of HNO_3 (1 : 4), When solution is complete wash into a graduated liter flask. add 75 cc. of H_2SO_4 (1:1), cool, and make up to the mark with water. Transfer to a large beaker, rinsing out the flask with 25 cc. of water. Mix thoroughly, allow to settle and filter off 900 cc., equivalent to a 100-g. charge. Evaporate in a large porcelain dish until only enough H_2SO_4 is left to moisten the residue. When cool, wash into a small distilling flask with 60 cc. of HCl (sp. gr. 1.20) and 20 cc. of water, cleaning the dish carefully. Add 10 g. of ferrous sulfate and distill, boiling to as small a volume as possible. When cool add 50 cc. more HCl (sp. gr. 1.20) and redistill. Pass H_2S gas through the cold distillate for 45 minutes. Filter, and weigh the As_2S_3 on a Gooch crucible, washing with cold water, alcohol and CS_2. After drying and weighing, redissolve with $(NH_4)_2$ CO_3 solution and reweigh the Gooch crucible, calculating the loss in weight to arsenic.

NOTE.

The 25 cc. of water added is equivalent to the volume of precipitated lead sulfate.

D. DETERMINATION OF REMAINING METALS.

SOLUTIONS REQUIRED.

Tartaric Acid.—Dissolve 50 g. of tartaric acid in 250 cc. of distilled water to which has been added 250 cc. HCl (sp. gr. 1.20).

METHOD.

Dissolve 222.23 g. of the sample in 1100 cc. of HNO_3 (1 : 4), using a 1300-cc. beaker. When solution is complete examine for color and turbidity. If clear, wash the solution at once into a 2000-cc. graduated flask. In case of a residue (Note 1), however, dilute to about 1100 cc. and allow to stand until the supernatant liquor is clear. Decant as much as possible into a 2000-cc. flask, filter the remainder and receive the filtrate in the same flask. Wash the precipitate well and then place it, together with the filter paper, in a 100-cc. beaker and add 20 cc. of the tartaric acid mixture. Heat to boiling and when the paper is well pulped allow to digest warm for 30 minutes. Now add 50 cc. of hot water, filter and wash. (Note 2.) Carefully dry the residue and ignite. If any appreciable residue remains, brush it into a small silver dish containing 1 g. of molten KOH. Fuse for 5 minutes, and after cooling dissolve in as little hot water as possible and add to the above mentioned tartaric acid filtrate. Render this solution just alkaline with ammonia and then just acid with HCl, and saturate hot with H_2S gas. After digesting for 30 minutes on the steam bath, pass H_2S through the solution again for 15 minutes. Filter and wash with slightly acidified H_2S water. Reject the filtrate. Wash the sulfides from the paper into the original beaker and add 5 cc. of KOH solution (1 : 5) for every 25 cc. volume present. Digest hot for 5 minutes and filter through the original paper into a small flask graduated to 110 cc. After washing with H_2S water containing a little of the KOH solution, cool the filtrate and make up to the mark. Mix and reserve 100 cc. as alkaline sulfide solution No. 1. The precipitate may be discarded.

Add slowly to the main solution in the 2000-cc. flask 150 cc. of H_2SO_4 (1 : 1). After cooling and filling up to the mark, pour into a clean 3-liter flask provided with a rubber stopper. Rinse the flask out with 50 cc. of water, which is equivalent to the volume of lead sulfate present and is added to the portion. After mixing thoroughly by shaking, allow the precipitate to settle and filter off 1800 cc. of the liquid. This is equivalent to a 200-g. charge. Place this in a No. 9 porcelain evaporating dish and evaporate, first over a free flame and later on the hot plate until only enough H_2SO_4 is left to moisten the residue remaining. Add 50 cc. of water and, after digesting warm for a short time, wash the solution into a 250-cc. beaker, cleaning the dish carefully. Allow the solution to digest on the steam bath for 4 or 5 hours. (Note 3.) Then filter, wash and evaporate the filtrate to 200–250 cc. Place any residue (Note 4), together with the filter paper, in a 100-cc. beaker and treat with 20 cc. of the tartaric acid mixture. Boil for 5 minutes, dilute with 50 cc. of hot water and filter. Make the filtrate alkaline with ammonia and just acid with HCl, and obtain the tin, antimony and arsenic as previously described, reserving the whole of the alkaline sulfide solution as solution No. 2. Reject the sulfide residue.

To filtrate from the lead sulfate, add ammonia until the neutral point is reached, and then for every 50 cc. of the solution present add 2 cc. of HCl (sp. gr. 1.20). Pass H_2S gas into the hot solution until saturated, digest for 30 minutes on the steam bath and again pass H_2S gas into the solution. Filter and wash with H_2S water slightly acidified. (Note 5.) Separate tin, antimony and arsenic in the precipitate with KOH solution as usual, obtaining an alkaline sulfide solution No. 3. (Note 6.)

To sum up, three alkaline sulfide solutions have been obtained, containing tin, antimony and arsenic, a precipitate of metallic sulfides containing copper, lead, etc., and a solution containing iron, zinc, nickel, etc.

NOTES.

1. A residue indicates the presence of antimony, tin, possibly arsenic, or sulfur as lead sulfate.

2. It has been found that even this treatment occasionally fails to dissolve stannic acid completely.

3. If it is preferred, allow solution to stand over night to insure the complete solution of all soluble salts.

4. Any residue of lead sulfate may contain some tin, antimony, or possibly arsenic.

5. The filtrate will contain any iron, zinc, nickel, cobalt and manganese; while in the precipitate will be found any copper, cadmium, lead, silver, bismuth, tin, antimony and arsenic.

6. When separating the sulfides of arsenic, antimony and tin from sulfides of copper, lead, etc., it is necessary to wash all the sulfides back into the beaker in which they were precipitated. These sulfides sometimes cling so tenaciously to the paper that in dislodging them more water than the 25 cc. specified is required. In this case allow the sulfides to settle and then decant the clear supernatant liquor through the filter until the volume is reduced to 25 cc. Before rejecting the decanted fluid always test with H_2S water.

In washing sulfide precipitates with water, much trouble is experienced from the tendency of the precipitate to pass through the filter in the colloidal form. This is particularly true in washing sulfides that have been digested with KOH. Time and trouble will be saved by washing all the sulfides precipitated from mineral acid solutions with H_2S water containing a little of the acid in which they were precipitated. The same is true of sulfides precipitated in or filtered from alkaline solution.

When working with alkaline solutions in which tin is to be determined, avoid the use of Jena or other glass that contains zinc. The zinc content of the glass may influence the result.

DETERMINATION OF ANTIMONY AND TIN.

SOLUTIONS REQUIRED.

Potassium Iodide.—Dissolve 100 g. in a liter of distilled water.

Standard Sodium Thiosulfate.—Dissolve 24.8 g. of $Na_2S_2O_3 \cdot 5H_2O$ in 1000 cc. of distilled water, and allow to stand for 24 hours. Standardize against Antimony Metal c. p., using same quantity of reagents and same procedure as under method. Each cubic centimeter is equivalent to approximately 0.006 g. of antimony.

METHOD.

Wash the alkaline sulfide solutions Nos. 1, 2, and 3 into a 600-cc. beaker, and acidify with 5 cc. of HNO_3 (sp. gr. 1.42) and 20 cc. of HCl (sp. gr. 1.20). Evaporate the solution to dryness on the steam bath. Dissolve the residue in 200 cc. of water, add 10 g. of oxalic acid and 10 g. ammonium oxalate and heat the solution until it is clear. Then pass H_2S gas through the boiling solution for 45 minutes. Filter off the precipitate, consisting of arsenic and antimony sulfides, and wash with hot water. Determine tin electrolytically in the filtrate, continuing the electrolysis until all the oxalic acid is decomposed and the solution becomes alkaline. Dissolve the deposit on the cathode with a small amount of HCl and examine qualitatively for tin.

Dissolve the sulfides of arsenic and antimony in KOH as usual, collecting the filtrate in a 500-cc. Erlenmeyer flask. Add 50 cc. of HCl (sp. gr. 1.20) and boil the solution until about 30 cc. are left. Expel the arsenic as chloride. Now oxidize the solution with a pinch of $KClO_3$ and boil until no more chlorine remains. Cool and add 5 cc. potassium iodide solution. Titrate the liberated iodine with N/10 sodium thiosulfate solution, using carbon disulfide as an indicator.

DETERMINATION OF COPPER AND CADMIUM.

SOLUTIONS REQUIRED.

Sodium Chloride (Solution No. 1).—Dissolve 1 g. NaCl in 100 g. distilled water.

Sodium Chloride (Solution No. 2).—Dissolve 10 g. NaCl in 100 g. distilled water.

Standard Potassium Cyanide.—Dissolve 2 g. of KCN in a liter of distilled water and standardize against a known amount of copper as treated in the analysis.

Sodium Carbonate (Solution No. 1).—Dissolve 50 g. Na_2CO_3 in 1 liter of distilled water.

Sodium Carbonate (Solution No. 2).—Dissolve Na_2CO_3 in distilled water to saturation.

METHOD.

(*a*) *Determination Where Copper Exceeds 0.0025 per cent.*

Place the filter containing the sulfides in a 100-cc. beaker and add 20 cc. of HNO_3 (1 : 4). Heat with occasional stirring until the paper is thoroughly pulped and the sulfides are completely dissolved. Filter into a 250-cc. beaker Dry the residue, which generally contains a small amount of copper, ignite in a porcelain crucible, boil with 5 cc. of HNO_3 (1 : 1), and wash into the main portion, keeping the volume below 100 cc. Render it strongly alkaline with ammonia, and add 5 g. of potassium cyanide, then saturate it in the cold with H_2S gas. (Note 1.) Filter the solution and evaporate the filtrate to a volume of 20 to 30 cc. in a 4-in. porcelain casserole. Boil until solution is complete. Add 20 cc. of H_2SO_4 (1 : 1) and evaporate the solution under a hood until dense fumes of H_2SO_4 escape. Cool, dilute, and warm until copper sulfate is all dissolved. Now filter, if necessary, into a 200-cc. beaker, render just alkaline with ammonia, make acid by the addition of 3 cc. of HNO_3 per 100 cc. solution, and electrolyze for copper.

Dissolve the precipitate of sulfides in the usual manner with 20 cc. of HNO_3 (1 : 4). Add 1 cc. NaCl solution No. 1 to the solution, still containing the pulped filter, and digest for ½ hour. Filter off the AgCl, wash and reject. Make the filtrate, not exceeding 100 cc., alkaline with a slight excess of Na_2CO_3 and add 5 g. of KCN. Digest for 1 hour. Filter and wash with Na_2CO_3 solution No. 1. Reject the precipitate of bismuth. Now add a few cubic centimeters of ammonium sulfide solution to the filtrate to precipitate any cadmium as yellow cadmium sulfide. Filter upon a weighed Gooch crucible and weigh as cadmium sulfide. (Note 2.)

NOTES.

1. Copper remains in the solution while lead, silver, bismuth and cadmium are precipitated.

2. If an appreciable amount of cadmium sulfide is found, it should be converted to and weighed as cadmium sulfate, according to method for cadmium under Standard Methods of Chemical Analysis of Spelter (Serial Designation: B 38) of the American Society for Testing Materials.

(*b*) *Determination Where Copper is Less than 0.0025 per cent.* Place the paper containing the sulfides in a porcelain crucible, dry carefully and ignite. When the carbon has been all burned off, cool and dissolve the residue in 5 to 10 cc. of HNO_3 (1:1). After evaporating to a volume of 1 to 2 cc., add 1 cc. of H_2SO_4 (1:1). Then evaporate the solution until fumes appear, cool, dilute, add a few drops of NaCl solution No. 2, and filter off the lead sulfate and silver chloride. Again evaporate the filtrate until fumes of H_2SO_4 appear, and when cold dilute and neutralize with Na_2CO_3 solution No. 2. Then add about six drops of concentrated ammonia and titrate the solution with standard KCN solution until the blue color is discharged.

The cadmium can be obtained by making this solution, titrated for copper, strongly alkaline, diluting a little, and adding 5 g. of KCN. Saturate the solution cold with H_2S gas, filter, discard the filtrate and treat the precipitate for cadmium as described in Method (*a*).

DETERMINATION OF IRON.

METHOD.

Evaporate the filtrate containing iron, zinc, etc., to 100 cc. and oxidize with a few drops of HNO_3. Separate the iron with ammonia as usual, making two separations, and receive the filtrate in a 500-cc. Erlenmeyer flask. Redissolve the iron hydroxide with hot HCl (1 : 1) or dilute H_2SO_4 and determine the iron volumetrically by any of the standard methods.

DETERMINATION OF ZINC.

METHOD.

Add to the filtrate from the iron hydroxide 1 cc. of cochineal indicator, and render just neutral with HCl. Then add 15 drops of twice normal HCl for each 100 cc. of the solution. Saturate cold with H_2S gas and allow the flask, loosely stoppered, to stand over night. Filter and wash with H_2S water acidified in the same manner as above described. Dry the precipitate of zinc sulfide, carefully ignite in a porcelain crucible and weigh as zinc oxide.

DETERMINATION OF NICKEL AND COBALT.

SOLUTIONS REQUIRED.

Hydrogen Sulfide Wash Water.—To each 100 cc. of hydrogen sulfide water add 20 cc. neutral ammonium acetate.

METHOD.

Render the filtrate just alkaline with ammonia and saturate with H_2S. Heat to boiling and then make just acid with acetic acid, add 20 cc. of neutral ammonium acetate solution, and boil until the sulfides of nickel and cobalt separate out. Filter and wash with warm H_2S wash water. Dry the precipitate and paper in a porcelain crucible and carefully ignite. If there is an appreciable amount of residue after ignition, dissolve by boiling with 10 cc. of aqua regia, wash into a 250-cc. beaker, add 10 cc. of H_2SO_4 (1 : 1), evaporate until fumes appear, cool, dilute to 200 cc., make alkaline with ammonia, and add 15 cc. of concentrated ammonia. Then electrolyze the solution and weigh the nickel and cobalt as such.

NOTES.

If the amount of nickel and cobalt is small it can be weighed as oxide.

If the filtrate from the nickel and cobalt sulfides shows a brown color, it indicates that the precipitation has not been complete. In this case render the solution ammoniacal and repeat the above process.

DETERMINATION OF MANGANESE.

SOLUTIONS REQUIRED.

Standard Potassium Permanganate—Mix 10 cc. N/10 $KMnO_4$ and 100 cc. of distilled water. Each cubic centimeter is equivalent to approximately 0.00011 g. Mn.

Dilute Sulfuric Acid.—Add 25 cc. concentrated H_2SO_4 to 1000 cc. of distilled water.

Nitric Acid Wash.—Add 300 cc. HNO_3 to 1000 cc. of distilled water.

METHOD.

Evaporate the filtrate, which should now contain only manganese, to dryness in a porcelain dish and heat carefully over an Argand burner until all the ammonium salts have been driven off. (Note 1.) After cooling, moisten the residue with a little HCl and warm until dissolved. Add 1 cc. of H_2SO_4 (1 : 1) and evaporate the solution until fumes appear, continuing the fuming until nearly all the H_2SO_4 has been driven off. Cool, and add 50 cc. of HNO_3 (1 : 3) and 0.5 g. of sodium bismuthate. (Note 2.) Boil the solution until the pink color is destroyed. If any manganese is precipitated, dissolve by the addition of a few cubic centimeters of a dilute sodium thiosulfate solution. In this case the solution must be again boiled until freed from all fumes. After cooling, add an excess of sodium bismuthate, stir a few minutes and filter through ignited asbestos into a 100-cc. Nessler tube. Wash with dilute HNO_3 (Nitric Acid wash) and make the filtrate up to the mark. Into another similar tube put 100 cc. of dilute H_2SO_4 which has been made very faintly pink with potassium permanganate solution. Now add standard solution of potassium permanganate from a burette until the color of the sample is exactly matched.

NOTES.

1. It is best to bake here over a Bunsen flame until all the organic matter has been destroyed.

2. The HNO_3 must be freed from nitrous fumes, by passing a current of air through the acid for ½ hour.

STANDARD METHODS OF CHEMICAL ANALYSIS
OF
SPELTER.

Serial Designation: B 38 – 21.

These methods are issued under the fixed designation B 38; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED AND PRINTED AS SEPARATE STANDARD, 1921.

The methods that follow are based on the Report of the Sub-Committee on Methods of Analysis of Non-Ferrous Alloys for the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society, approved by the Supervisory Committee on Standard Methods of Analysis of that Society.[1] These methods were originally proposed by Elliott and Storer[2] and Price[3] whose work has been checked and elaborated by the members of the Committee of the American Chemical Society and of this Society.

The methods are those generally accepted in the United States for standard analysis in all the large laboratories of both producers and consumers of zinc and zinc products.

The Electrolytic and Lead-Acid methods described below are believed to be of equal merit, so far as accuracy is concerned, but where laboratories are equipped for electrolysis the electrolytic method is preferred as a time saver.

DETERMINATION OF LEAD
BY THE
ELECTROLYTIC METHOD

APPARATUS.

Platinum cylindrical gauze electrodes containing approximately 400 meshes per sq. cm. (50 meshes per linear inch) are recommended for anode and cathode. They should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinders. The anode should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and electrically welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted. The cathode should be approximately 12 mm. in diameter by 30 mm. in height, the stem being of the same dimensions and welded in the same way as the anode.

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[1] *Journal of Industrial and Engineering Chemistry*, Vol. 7, 1915, p. 547.

[2] *Memoirs*, Am. Acad. Arts and Sciences, 8, Part 1, May 20 (1860).

[3] *The Chemical Engineer*, 9 (1909), 4.

METHOD.

Place 8.643 g. (Note 1) of the sample in a 400-cc. beaker, add sufficient water to cover and then add 30 cc. HNO_3 (sp. gr. 1.42) gradually. When action is complete, boil the solution for 10 minutes, wash off the watch glass, and transfer the solution to a 200-cc. electrolytic beaker, washing out the original 400-cc. beaker. Dilute to 125 cc. and electrolyze (Note 2) with a current of five amperes for 45 minutes. (Note 3.) Test the solution for complete precipitation of lead by washing the watch glasses and sides of the beaker, increasing the depth of the solution about 12 mm. Continue the current for 15 minutes and if the newly-exposed surface is still bright, wash the anode (Note 4) three or four times with distilled water, once with alcohol, and then dry in an oven (Note 5) at 210° C. for 30 minutes, cool in a desiccator and weigh.

The weight of the deposited PbO_2, in milligrams, divided by 100, gives the percentage of lead (Note 6).

NOTES.

1. The empirical factor weight, 8.643 g., is used instead of the theoretical one (8.660 g.) as dried dioxide contains some adherent and included water, not entirely expelled.

2. Before electrolyzing, the beaker should be covered with split watch glasses to prevent loss by spraying.

3. The time required for complete deposition is usually 30 to 45 minutes. For small amounts of lead 30 minutes will be found sufficient.

4. The washing should be done immediately, as the deposit of PbO_2 tends to dissolve.

5. The anode may also be dried on a hot plate, although a drying oven is to be preferred.

6. The PbO_2 deposit can be readily removed by immersing the anode in hot dilute solution of HNO_3 to which oxalic acid has been added, or by covering with dilute HNO_3 and inserting a rod of copper.

DETERMINATION OF LEAD BY THE LEAD ACID METHOD.

SOLUTIONS REQUIRED.

Lead Acid.—Pour 300 cc. of H_2SO_4 (sp. gr. 1.84) into 1800 cc. of distilled water; dissolve 1 g. of lead acetate in 300 cc. of distilled water and add to the acid solution with stirring. Allow to settle for several days and siphon off the clear solution through a thick asbestos pad. (Note 1.)

Nitric Acid.—Mix 1000 cc. of HNO_3 (sp. gr. 1.42) with 1000 cc. of distilled water.

Alcohol.—Mix 1000 cc. of ethyl alcohol (95-per-cent) with 1000 cc. of distilled water.

METHOD.

Place sample (Note 2) of 25, 15, 10, or 5 g. in a 350-cc. beaker and add 300, 180, 120 or 60 cc., respectively, of lead acid. After all but about 1 g. is dissolved, filter on a close filter and wash out the beaker twice with lead acid from a wash bottle. Wash the undissolved matter from the filter into the original beaker with water and dissolve with 10 cc. of HNO_3. Add 40 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. When cool, add 35 cc. (Note 3) of water, heat to boiling and add the first filtrate (Note 4), stir well and allow to stand over night (Note 5). Filter on a Gooch crucible, wash with lead acid, then with alcohol-water mixture, and finally with alcohol alone. Set the Gooch crucible inside of a larger porcelain crucible (Note 6) and heat for five minutes at the full heat of a Tirrill burner. Cool and weigh as $PbSO_4$.

NOTES.

1. When lead acid is used, it is unnecessary to consider the solubility of $PbSO_4$, since the solution is always brought back to the same volume as the lead acid used originally, consequently it will retain no $PbSO_4$ from the sample.

2. The amount of sample taken is governed by the grade of spelter:

Grade No. 1, 25 g.	Grade No. 3, 10 g.
Grade No. 2, 15 g.	Grade No. 4, 5 g.
Grade No. 5, 5 g.	

3. The 35 cc. of water added is the quantity of water evaporated from the lead acid.

4. The first filtrate, which contains the greater part of the zinc, may also contain a small amount of $PbSO_4$.

5. It is preferable to allow the solution and precipitate of $PbSO_4$ to stand over night, although this time may be shortened to not less than five hours.

6. The Gooch crucible is heated inside of a porcelain crucible to avoid reduction of the $PbSO_4$ by flame gases and mechanical disintegration of the asbestos mat.

DETERMINATION OF IRON.

SOLUTIONS REQUIRED.

Dilute Ammonia Water.—Mix 100 cc. of NH_4OH (sp. gr. 0.90) with 1000 cc. of distilled water.

Sulfuric Acid (1 : 4).—Mix 250 cc. of H_2SO_4 (sp. gr. 1.84) with 1000 cc. of distilled water

Sulfuric Acid (1 : 1).—Mix 500 cc. of H_2SO_4 (sp. gr. 1.84) with 500 cc. of distilled water.

Dilute Sulfuric Acid for Reductor.—Mix 50 cc. of H_2SO_4 (sp. gr. 1.84) with 1000 cc. of distilled water. This solution is used boiling hot.

Potassium Permanganate.—Dissolve 0.2 g. of $KMnO_4$, C.P., in 1000 cc. of distilled water. Allow to stand for several days in aglass-stoppered bottle in a dark closet, and then filter through prepared asbestos. Standardize against 0.020-g. portions of pure sodium oxalate, dissolved in 200 cc. of the dilute H_2SO_4 for reductor. Each cubic centimeter of $KMnO_4$ is equivalent to approximately 0.00033 g. of iron.

METHOD.

Place 25 g. of the sample in a tall 700-cc. beaker and dissolve cautiously with 125 cc. of HNO_3 (sp. gr. 1.42). Boil, dilute to about 300 cc., add 10 g. of NH_4Cl and then ammonia water (sp. gr. 0.90) until the precipitated $Zn(OH)_2$ has redissolved. Boil, let settle and filter on an 11-cm. filter paper (Note 1). Wash with dilute ammonia water and then with hot water until free from chlorides. Dissolve precipitate from the paper with hot H_2SO_4 (1 : 4), add 40 cc. of H_2SO_4 (1 : 1), cool, and pass through a Jones reductor (Note 2). Wash out the reductor first with 150 cc. of dilute H_2SO_4 for reductor and then with 100 cc. of distilled water and titrate with standard $KMnO_4$ solution (Note 3).

NOTES.

1. A filter paper which will retain $Fe(OH)_3$ and filter rapidly should be used. Whenever the amount of iron is at all large or when great accuracy is demanded, a second precipitation of $Fe(OH)_3$ should be made by dissolving the precipitate on the paper in hot dilute HCl, adding ammonia water and filtering, in order to remove all traces of nitrates.

2. The reductor should be clean, preferably washed out with 150 cc. of dilute H_2SO_4 and 100 cc. of water first. If, before passing through the reductor, a large amount of $PbSO_4$ is present, it is well to filter it off so as to prevent it from clogging the reductor. A small quantity of liquid should always be left in the reductor funnel, and air should never be allowed to enter the body of the reductor. For description and further details of use of reductor, see "The Chemical Analysis of Iron," by A. A. Blair, or "Quantitative Chemical Analysis," by H. P. Talbot.

3. A blank determination should be made on corresponding amounts of acid and water passed through the reductor and the results should be corrected accordingly. About 0.5 cc. of the $KMnO_4$ solution will be required to give a permanent coloration to the solution.

DETERMINATION OF CADMIUM GRAVIMETRICALLY.

SOLUTIONS REQUIRED.

Sulfuric Acid (1 : 1).—Mix 500 cc. of H_2SO_4 (sp. gr 1.84) with 500 cc. of distilled water.

Sulfuric Acid (1 : 5).—Mix 200 cc. of H_2SO_4 (sp. gr. 1.84) with 1000 cc. of distilled water.

Hydrochloric Acid (1 : 3).—Mix 250 cc. of HCl (sp. gr. 1.20) with 750 cc. of distilled water.

METHOD.

Place 25 g. of drillings in a tall 500-cc. beaker; add 250 cc. of water and 55 cc. of HCl (sp. gr. 1.20) and stir. When the action has almost ceased add more acid with stirring, using about 2 cc. at a time and allowing to stand after each addition, until finally all but about 2 g. of the zinc has been dissolved. (Note 1.) Filter, first transferring one of the undissolved pieces of zinc to the filter, and wash twice with water. Discard the filtrate. Wash the undissolved matter on the filter paper into the 500-cc. beaker, cover and dissolve in 10 cc. of water and 10 cc. of HNO_3 (sp. gr. 1.42). Transfer to a casserole, add 20 cc. of H_2SO_4 (1 : 1) and evaporate until fumes appear. Take up with 100 cc. of water, boil, cool, and let settle over night. (Note 2.) Filter off the $PbSO_4$ on paper, wash twice with water, retain the filtrate but discard the paper and precipitate. Dilute the filtrate to 400 cc., add about 10 g. of NH_4Cl, and pass H_2S gas through for 1 hour (Note 3). Allow to stand until the precipitate has settled, and filter off the impure CdS (Note 4) on a loose-bottom Gooch crucible. Remove the precipitate by punching out the bottom into a tall 200-cc. beaker, wiping off the sides of the crucible with a little asbestos pulp. Add 60 cc. of H_2SO_4 (1 : 5) and boil for 30 minutes (Note 5). Filter, wash, and dilute to 300 cc., add about 5 g. of NH_4Cl and precipitate with H_2S gas as before (Note 6). Repeat, making a third precipitation if the amount of cadmium present is large (Note 7). After the final precipitation, let settle, filter and transfer to a weighed platinum dish, cover, and dissolve in HCl (1 : 3). Dissolve the precipitate remaining on the paper in hot HCl (1 : 3) and add also to the solution in the platinum dish (Note 8). Add 10 cc. of H_2SO_4 (1 : 1) and evaporate the solution until copious fumes are evolved (Note 9). Remove the excess of H_2SO_4 by heating the dish cautiously, and finally heat to between 500 and 600° C. Cool and weigh as $CdSO_4$.

Notes.

1. The addition of HCl will dissolve the zinc and a small amount of the cadmium. By adding the acid in small quantities, *i.e.*, keeping the acidity low, and also keeping the solution cold, the amount of cadmium dissolved will be small. Since it requires some time to completely reprecipitate any cadmium dissolved, it is desirable for the solution to stand over night following the addition of the 55 cc. of HCl at the start. For the same reason the solution should be allowed to stand after the last addition of acid, and care be taken that the stated amount of spelter remain in the undissolved residue. If the solution is heated, or if time is not allowed for the action of the acid to cease completely, small amounts of cadmium may pass into the solution and be lost.

Equally satisfactory, or in some cases more satisfactory results are obtained by using H_2SO_4 to dissolve the major portion of the zinc. The rate of solution is slower and the tendency for cadmium to pass into solution less. The quantity of acid required can be calculated, measured out at the beginning and small quantities added from time to time as the action becomes slow.

2. It is desirable to allow it to settle over night to precipitate all the $PbSO_4$ from the solution and to give good conditions for filtering.

3. It is occasionally necessary to add a drop or two of ammonia water to the solution to start the precipitation of CdS.

4. All the cadmium will be precipitated as sulfide together with some ZnS. The major portion of the zinc will remain in solution.

5. In case of high cadmium content, more acid may be required.

6. The second precipitation should give practically pure CdS.

7. A third precipitation will remove any uncertainty as to the completeness of the separation of cadmium from zinc.

8. A crucible may also be used if the volumes are kept small or evaporated before transferring to the crucible.

9. On evaporating to fumes, darkening of the solution may occur from filter paper shreds. This may be destroyed by diluting slightly with water and adding 5 cc. HNO_3 (sp. gr. 1.42) and again evaporating to fumes.

DETERMINATION OF CADMIUM
BY THE
ELECTROLYTIC METHOD.

Solutions Required.

Potassium Hydroxide. (Note 1).—Dissolve 20 g. of KOH, C.P., in 200 cc. of distilled water.

Potassium Cyanide (Note 2).—Dissolve 20 g. of KCN, C.P., in 200 cc. of distilled water.

APPARATUS.

See "Determination of Lead by the Electrolytic Method." The anode, as used in the lead determination, is here used as the cathode, and *vice versa*.

METHOD.

See "Determination of Cadmium Gravimetrically."

Dissolve the final precipitate of CdS in hot HCl (1 : 3), boil to remove H_2S, adding a few drops of HNO_3 (sp. gr. 1.42) near the end, and filter off the separated sulfur. Transfer the solution to a 200-cc. electrolytic beaker, add a drop or two of phenolphthalein and then KOH solution until a permanent red color is obtained. Add KCN solution with constant stirring until the precipitate of $Cd(OH)_2$ is completely dissolved (Note 3). Dilute to 150 cc. and electrolyze with a current of five amperes for two hours (Note 4). Test for completeness of deposition by washing the watch glasses and sides of the beaker to increase the depth of the solution. Continue electrolysis for twenty minutes and if the newly-exposed surface of the cathode is still bright, remove the beaker with electrolyte and wash the electrodes three times with distilled water and twice with ethyl alcohol (95-per-cent). Dry the cathode at 100° C., cool and weigh. The increase is metallic cadmium.

NOTES.

1. Pure NaOH may be used in place of KOH.
2. Pure NaCN may be used in place of KCN.
3. Avoid using an excess of KCN.
4. The test for completeness of deposition may be made after one hour when the quantity present is not large.

STANDARD METHODS OF CHEMICAL ANALYSIS OF ALLOYS OF LEAD, TIN, ANTIMONY AND COPPER.

Serial Designation: B 18 – 21.

These methods are issued under the fixed designation B 18; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted in Amended Form, 1921.

These methods apply particularly to white metal bearing alloys (known commercially as "Babbitt Metal") and to similar lead and tin base alloys.

Two sets of methods are here given. The first method is somewhat slow but is recommended as giving the more accurate results where the analysis of these alloys is of comparatively infrequent occurrence. The second method is rapid and is suitable for control work, giving good results after the analyst has become familiar with it.

I.—GENERAL METHOD.[1]

A. DETERMINATION OF LEAD, COPPER, ANTIMONY AND TIN.

DETERMINATION OF LEAD.

Solutions Required.

Mixed Acid.—Dissolve 20 g. of KCl in 500 cc. of water, add 400 cc. of HCl (sp. gr. 1.20), mix and add 100 cc. of HNO_3 (sp. gr. 1.42).

Alcohol-Hydrochloric Acid Mixture.—Mix 400 cc. of 95-per-cent ethyl alcohol and 100 cc. of HCl (sp. gr. 1.20).

Acid Ammonium Acetate.—To 500 cc. of NH_4OH (sp. gr. 0.90), add 500 cc. of water and then acetic acid (80-per-cent), until slightly acid to litmus.

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[1] G. W. Thompson's method. See *Journal*, Soc. Chem. Ind. Vol. 15, p. 179.

METHOD.

Dissolve 1 g. of the finely divided alloy by boiling in 70 to 100 cc. of "mixed acid" solution in a covered beaker. Add more "mixed acid" if a complete solution of the alloy is difficult to obtain, and continue boiling until evaporated to about 50 cc. Add 5 cc. of HCl (sp. gr. 1.20), cool in ice water until the bulk of $PbCl_2$ has crystallized out, then add slowly, with constant stirring, 50 cc. of alcohol (95-per-cent), continue stirring for a few minutes and cool in ice water for 10 minutes. Add 50 cc. more alcohol from a pipette, allow to stand in ice water for 20 minutes and filter through 9-cm. paper into an 800-cc. beaker. Wash by decantation three times with alcohol-hydrochloric acid mixture and finally wash the paper twice with the same mixture. Wash the $PbCl_2$ from the paper back into the beaker; wash paper several times with hot water, catching washings in beaker with the bulk of the chloride. Finally wash paper with hot acid ammonium acetate solution. Heat until all $PbCl_2$ is dissolved. Add 15 cc. of saturated solution of $K_2Cr_2O_7$; heat until precipitate is of good orange color; filter on weighed Gooch crucible; wash with water, alcohol and ether; dry at 110° C. and weigh. Calculate percentage of lead by the empirical factor 63.75.

NOTES

1. With proper manipulation, the $PbCl_2$ precipitate should contain consistently all but 0.003 g. of lead.

2. During the heating of the acid ammonium acetate to dissolve the $PbCl_2$, the solution should remain perfectly clear, any turbidity indicating the presence of tin or antimony, as even 1 mg. of tin or antimony will cause a slight but distinct turbidity.

DETERMINATION OF COPPER AND ANTIMONY.

SOLUTIONS REQUIRED.

Potassium Hydroxide.—Dissolve 100 g. of KOH in 500 cc. of water.

Potassium Cyanide.—Dissolve 3.5 g. of KCN in 1800 cc. of water and standardize against copper of known purity.

Sodium Thiosulfate.—Dissolve 24.8 g. of $Na_2S_2O_3.5H_2O$ in 1000 cc. of water, and allow to stand for 24 hours. Standardize against Antimony Metal c. p., using same quantity of reagents and same procedure as under (*c*) Determination of Antimony.

METHOD.

See "Determination of Lead."

Evaporate the filtrate from $PbCl_2$ filtration by boiling in the loosely covered 800-cc. beaker, and finally take to dryness on a water bath. Add 10 cc. of KOH solution and after a few minutes add 20 cc. of 3-per-cent H_2O_2. Add more KOH, if solution is acid, until an alkaline reaction is shown by litmus paper. Heat on the water bath for 20 minutes, add 10 g. of ammonium oxalate, 10 g. of oxalic acid, and 200 cc. of water and heat to boiling. Pass in H_2S for 45 minutes with solution near boiling; filter at once; and wash precipitate with hot dilute solution of oxalic acid saturated with H_2S, catching washings with filtrate.

Wash the precipitate of copper and antimony sulfides from the filter paper back into the beaker with the least amount of water possible; treat with 10 cc. of KOH solution; heat on water bath until the undissolved matter is distinctly black, filter through same paper into a 300-cc. Erlenmeyer flask. Wash the precipitate with hot water containing a small amount of K_2S.

(*a*) *Determination of Copper by Potassium Cyanide Titration.*

Dry and ignite the precipitate with paper in a small casserole, dissolve in nitric acid (sp. gr. 1.42), boil to expel nitrous fumes, neutralize with Na_2CO_3, add a few drops of NH_4OH and titrate with standard KCN solution.

(*b*) *Determination of Copper by Electrolytic Method.*

See "Determination of Copper by Potassium Cyanide Titration."

Dry and ignite the sulfide precipitate in a small casserole, dissolve in 10 cc. of HNO_3 (sp. gr. 1.42), boil until oxides of nitrogen are expelled and add 50 cc. of distilled water. Transfer to a tall 200-cc. beaker, wash out casserole, add 5 cc. of H_2SO_4 (sp. gr. 1.84) and determine copper by electrolysis. See the determination of copper by the electrolytic method in the Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.

NOTES.

1. On filter after heating with KOH solution, the copper remains as sulfide with a small amount of lead sulfide which failed to be precipitated as

chloride. If it is desired to determine this lead, it can be done by separation rom the copper by ordinary methods.

2. If the amount of antimony and copper is small (less than 10 mg.) the lead which failed to be precipitated as chloride may also fail to come down as sulfide on passing H_2S through the oxalic solution. It will remain in the filtrate from the sulfides and be deposited electrolytically with the tin on the cathode. This can be prevented by adding an oxalic acid solution of a pure antimony salt containing about 100 mg. of antimony just before passing H_2S. In this case antimony must be determined on a separate portion.

3. If the amount of copper present is from 8 to 10 mg. or more, it should be determined by the electrolytic method. In this case, the small amount of lead precipitated as sulfide with the copper is deposited on the anode as PbO_2 and may be weighed, calculated to lead by factor 86.43 and added to that obtained under "Determinations of Lead".

(*c*) *Determination of Antimony.*

See "Determination of Copper by Potassium Cyanide Titration."

Add 50 cc. of HCl (sp. gr. 1.20) to the KOH solution of antimony sulfide, and boil down to small volume until all arsenic has been expelled as arsenious chloride.

Add 25 cc. of HCl (sp. gr. 1.20) and 1 g. of $KClO_3$ and boil until colorless. Filter into a 300-cc. Erlenmeyer flask, through glass wool if sulfur has separated, wash out original flask with HCl (sp. gr. 1.20), cool, add 1 g. of KI, 1 cc. of CS_2, and titrate with standard thiosulfate solution.

DETERMINATION OF TIN.

APPARATUS FOR ELECTROLYSIS.

Electrodes.—Cylindrical cathodes of platinum wire gauze—2 by $1\frac{3}{8}$ in. diameter.

Platinum wire spiral anodes.

METHOD.

See "Determination of Copper and Antimony."

Concentrate the filtrate and washings from the precipitated sulfides, if necessary, to a volume of 200 cc. and add 5 g. more of oxalic acid in case the amount of tin is over 0.5 g. Electrolyze until the solution reacts alkaline, using a current of about 0.5 amperes. Remove the cylinder; wash twice with distilled water and once with 95-per-cent ethyl alcohol; dry at 110° C. and weigh.

NOTE.

If the electrolysis is carried out over night it will usually be found by morning that the solution has become alkaline and it may be taken for granted that the tin has all been precipitated on the cathode. The best results are obtained by regulating the current, or the time, so as to render the solution alkaline only a very short time before the cathode is to be removed. The cathode should be placed close to the bottom of the beaker to insure proper agitation of the electrolyte.

B. DETERMINATION OF ARSENIC.

SOLUTIONS REQUIRED.

Ferric Chloride.—Solution of specific gravity 1.43.

Ammonium Carbonate.—Dissolve 75 g. in 500 cc. of water.

METHOD.

Weigh 1 g. of sample into a 250-cc. distillation flask and add 10 cc. of $FeCl_3$ solution, 60 cc. of HCl (sp. gr. 1.20) 20 cc. of water and 5 g. of KCl. Connect the flask with a condenser, heat slowly until solution is complete and boil down to as small a volume as possible, catching distillate in a tall 400-cc. beaker. Cool flask, add 50 cc. HCl (sp. gr. 1.20) and redistill as before, catching distillate in same beaker. Cool distillate and pass H_2S through for one hour, allow to settle and filter the arsenious sulfide on a Gooch crucible. Wash twice with HCl (1 : 4), four times with cold water, three times with alcohol and four times with CS_2. Dry at 110° C. for 10 minutes, and weigh after cooling. Dissolve the arsenious sulfide with $(NH_4)_2 CO_3$ solution, wash thoroughly with water, dry for 30 minutes at 110° C. and reweigh after cooling. The difference in weights multiplied by 0.60911 gives the percentage of arsenic.

II.—RAPID METHOD FOR CONTROL WORK.[1]

A. DETERMINATION OF LEAD AND COPPER.

SOLUTIONS REQUIRED.

"*Lead Acid.*"—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84) and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate c. p.

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[1] See "The Analysis of Alloys of Lead, Tin, Antimony and Copper," by D. J. Demorest, *Journal Ind. and Eng. Chem.*, Vol. V, p. 842; "Rapid Analysis of Alloys for Tin, Antimony, and Arsenic," by F. A. Stief, *Journal Ind. and Eng. Chem.*, Vol. VII, p. 211; and "Technical Analysis of Brass," 1917. Price and Meade, p. 182.

in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and siphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD.

(*a*) *Determination of Lead.*

In a covered 300-cc. Erlenmeyer flask dissolve 1 g. of the alloy in 20 cc. of H_2SO_4 (sp. gr. 1.84); heat the solution nearly to boiling until the metal is completely decomposed and the $PbSO_4$ is white (this may take 30 minutes or more) and finally boil for several minutes. Allow to cool, but not below 60° C., and then add slowly 50 cc. of water while the solution is agitated. Heat to boiling for several minutes in order to insure complete solution of antimony sulfate. Allow the $PbSO_4$ to settle out until the solution is clear, not letting the temperature fall below 60° C. If the liquid does not clear quickly it must be heated longer. When clear, pour the solution through a weighed porcelain Gooch crucible with asbestos mat, decanting the solution as completely as possible without allowing more than a very small amount of $PbSO_4$ to go over into the crucible. Now add 10 cc. more of H_2SO_4 (sp. gr. 1.84) to the $PbSO_4$ in the original flask, and boil for several minutes. Cool, add slowly 30 cc. of water, and again heat to boiling for a few minutes; allow the solution to cool to about 60° C. and completely transfer the $PbSO_4$ to the Gooch crucible. Wash with lead acid, retaining the filtrate and these washings for the copper determination. Remove the beaker containing these solutions and wash out the lead acid with dilute alcohol; set the Gooch crucible inside a porcelain crucible; dry and ignite for five minutes at the full heat of a Tirrill burner; cool and weigh as $PbSO_4$, which contains 68.29 per cent lead.

(*b*) *Determination of Copper.*

To the filtrate from the $PbSO_4$, which contains the copper and which has been transferred to an Erlenmeyer flask, add NH_4OH (sp. gr. 0.90) until the solution is slightly alkaline; then add 2 cc. of H_2SO_4 (sp. gr. 1.84); heat nearly to boiling; add 2 g. of Na_2SO_3 and when this is entirely dissolved add 1 g. of KCNS dissolved in 10 cc. of water. Shake well and allow the precipitated CuCNS to settle for one hour while the solution is kept hot. Filter on a close filter paper, wash with cold water and ignite paper and precipitate in a porcelain crucible. Proceed by one of the two following methods:

(1) Dissolve in HNO_3 (sp. gr. 1.42), add 5 cc. H_2SO_4 (sp. gr. 1.84); evaporate until fumes of H_2SO_4 are evolved. Dilute to about 100 cc. with distilled water. Add 1.5 cc. of HNO_3 (sp. gr. 1.42) and determine copper by electrolysis. See the "Determination of Copper by the Electrolytic Method," Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.

(2) Dissolving the ignited precipitate in HNO_3 (sp. gr. 1.42), as in (1); boil to expel nitrous fumes, neutralize with Na_2CO_3 and determine volumetrically with cyanide as in *A* of "General Method."

NOTE.

If the amount of copper is very small it may escape detection by this method, in which case it should be determined as in *A* of "General Method."

B. DETERMINATION OF ARSENIC, ANTIMONY AND TIN.

APPARATUS.

Arsenic Still.—A condenser is made from glass tubing in the form of a letter *S*, about 18 in. long and $\frac{1}{2}$ in. in inside diameter, tapering to about $\frac{1}{4}$ in. at the upper end and to about $\frac{1}{8}$ in. at the lower end. One curve is nearly filled with water, and is submerged in cold water in a 500-cc. beaker. The lower end dips into about 75 cc. of water in a 300-cc. beaker and the upper end is connected by a delivery tube with a 300-cc. Florence flask, closed with a rubber stopper which is fitted with a delivery tube and with a thermometer reaching to about 1 in. above the surface of the liquid in the flask.

SOLUTIONS REQUIRED.

Iodine.—Dissolve 10.7 g. of iodine in 50 cc. of distilled water which contains 20 g. of KI in solution and dilute to 1000 cc. with distilled water. Standardize against pure tin having exactly the same conditions for titration as are specified for the analysis of the alloy. Each cubic centimeter is equivalent to approximately 0.00500 g. of tin or 0.00315 g. of arsenic.

Potassium Permanganate.—Dissolve 2.7 g. of $KMnO_4$ in distilled water, filter through asbestos, and dilute to 1000 cc.

with distilled water. Standardize against pure antimony having exactly the same conditions for titration as are specified for the analysis of the alloy. Each cubic centimeter is equivalent to approximately 0.00500 g. of antimony or 0.00465 g. of iron.

Ferrous Ammonium Sulfate.—Dissolve 12.4 g. of ferrous ammonium sulfate crystals in 950 cc. of distilled water and add 50 cc. of H_2SO_4 (sp. gr. 1.84).

Starch.—To 1000 cc. of boiling water, add a cold suspension of 6 g. of starch in 100 cc. of distilled water; cool, add a few drops of chloroform and mix thoroughly.

METHOD.

(*a*) *Determination of Arsenic.*

In a 300-cc. Florence flask, dissolve 0.5 g. of the alloy in exactly 8 cc. of H_2SO_4 (sp. gr. 1.84). The metal must be finely divided, preferably in the form of thin foil-like shavings, although sawings or very fine drillings may be used. Heat the solution to boiling; cool, add about 5 cc. of water and a bulk of about 0.5 cc. of clean granulated pumice stone and boil the covered solution very gently for about five minutes, or until the strong odor of SO_2 can no longer be detected. Finally, being careful to have 5 cc. of water present, cool the solution to about 18° C. and cautiously add 20 cc. of HCl (sp. gr. 1.20). Insert in the flask a rubber stopper fitted with a thermometer and delivery tube and connect the delivery tube with the "*S*" condenser. Heat the solution to gentle boiling for from 10 to 15 minutes, keeping the vapor temperature at 107° C. for at least 5 minutes. Wash out the condenser into a 300-cc. beaker and add an excess of about 2 g. of $NaHCO_3$. Bring the volume of the solution to about 200 cc.; warm to about 27° C. and titrate with standard iodine solution and starch to the appearance of a deep blue color.

NOTE.

A blank determination should be made on corresponding amounts of reagents treated as above, and the results should be corrected accordingly.

(*b*) *Determination of Antimony.*

Cool the solution which remains in the flask after the arsenic distillation; add about 130 cc. of cold, recently-boiled distilled water, to which has been added about 3 cc. of HCl (sp. gr. 1.20) and titrate with standard $KMnO_4$ solution to the appearance of a decided permanent pink color. From a burette add an excess of standard ferrous ammonium sulfate solution until the pink color is discharged and then titrate with standard $KMnO_4$ solution to the reappearance of a pink color.

(*c*) *Determination of Tin.*

If the sample does not contain 14 per cent (or 0.07 g.) of antimony, add enough dissolved $SbCl_3$ to the solution to bring the contents of antimony up to about 0.07 g. for the purpose of insuring perfect reduction of the tin and uniform conditions for the titration. Then add exactly 6 cc. of H_2SO_4 (sp. gr. 1.84) and 60 cc. of HCl (sp. gr. 1.20) and add about 6 in. of clean, soft No. 14 pure iron wire cut into 2-in. lengths and cleaned with dilute HCl just before using. Boil gently for 30 minutes, add about 6 in. more wire and boil 30 minutes longer. Remove from heat, close flask loosely with a rubber stopper and allow about two minutes for all air to be expelled by hydrogen and acid vapors. Close flask tightly and quickly place it in cold water, cooling the solution to about 20° C. Transfer the solution quickly to a 500-cc. beaker (leaving the iron wires in the flask) and rinse flask and contents with 150 cc. of cold, recently-boiled distilled water. Add rinsings to main solution in the beaker, bring final volume to about 300 to 350 cc. and titrate quickly with standard iodine solution and starch to the appearance of a strong blue color.

NOTES.

A blank determination should be made on corresponding amounts of reagents treated as above, and the results should be corrected accordingly.

If the copper contents of the alloy is as high as about 3 per cent or over, it prevents a good end point in the tin titration when the tin percentage is low. Under such conditions, just before titrating, add about 1 g. of KI crystals, stir until nearly dissolved and titrate immediately. If allowed to stand too long at this point, trouble may be encountered due to the precipitation of some of the other constituents.

Other forms of pure iron may be employed, but the wire as above specified has been found convenient.

For accurate work it is desirable to reduce and titrate the solution of tin in an atmosphere of CO_2.

STANDARD METHODS OF CHEMICAL ANALYSIS
OF
MANGANESE BRONZE.

Serial Designation: B 27 - 19.

These methods are issued under the fixed designation B 27; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1918; ADOPTED, 1919.

GENERAL CONSIDERATIONS.

Methods are given for the determination of lead, using a large sample when lead is present up to about 0.2 per cent. A method is also given for the electrolytic determination of lead and copper in the same small sample when lead is present in amounts over 0.2 per cent.

In this alloy zinc is taken by difference. For a method of determining small amounts of zinc, see Standard Methods of Chemical Analysis of Gun Metal (Serial Designation: B 28) of the American Society for Testing Materials.

DETERMINATION OF COPPER
BY THE
ELECTROLYTIC METHOD.

APPARATUS FOR ELECTROLYSIS.

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

Anodes.—Platinum anodes may be of the spiral type when used in the determination of copper by electrolysis, or in the electrolytic determination of lead when it is present in amounts not over 0.2 per cent. When used in electrolytic determination of copper and lead together in samples containing 0.2 per cent lead or over, the anodes should be of wire gauze. Spiral anodes should be made from 1.02-mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm. Platinum gauze used in making anodes should contain approximately 400 meshes per sq. cm. (50 meshes per linear inch). The gauze should be formed into closed cylinders approximately 12 mm. in diameter and 30 mm. in height. The cylinders should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom. The stem should be made from 1.02-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 137 mm., and the gauze should be sand blasted.

METHOD.

In a 150-cc. beaker dissolve 1 g. of bronze in 10 cc. of HNO_3, sp. gr. 1.42. When the action has ceased, evaporate the solution to dryness, and bake thoroughly on the edge of a hot plate. Moisten thoroughly with HNO_3, sp. gr. 1.42, and after digesting for a short time dilute to 50 cc. with hot distilled water, heat to boiling, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. papers, keeping the solution hot, and receive the filtrate in a 200-cc. electrolysis beaker. Wash with boiling hot water. Add to the filtrate 5 cc. of H_2SO_4, sp. gr. 1.84, and evaporate until copious fumes of H_2SO_4 are evolved. Dilute to about 100 cc. with distilled water, add 1.5 cc. of HNO_3, sp. gr. 1.42, insert electrodes, cover with a pair of split watch-glasses and electrolyze. For each solution use a current over night of 0.5 ampere at approximately 10 volts, or else use a current of 4 amperes at approximately 10 volts continued for about 2½ hours. The latter case requires the use of gauze cathodes. When the solution is colorless, wash down cover glasses, electrodes, and sides of beaker, raising the level of the liquid slightly and continue the electrolysis about 15 minutes, noting whether or not copper is deposited on the newly exposed surface of the platinum. If no copper appears, transfer about 1 cc. of the colorless solution to the cavity of a porcelain test plate, and add a few drops of fresh H_2S water. If the slightest discoloration occurs continue the electrolysis, repeating the test. Remove the cathode quickly, rinse it in distilled water and then dip it in two successive baths of alcohol. Shake off the excess alcohol and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually as the alcohol burns. Weigh as metallic copper.

Accuracy.—Duplicate determinations should check within 0.10 per cent of copper.

NOTES.

In alloys of the type of manganese bronze, which carry considerable iron, it is impossible to remove the tin quantitatively as metastannic acid (H_2SnO_3), notwithstanding the preliminary baking. Upon testing (by the addition of H_2S water), the liquid in the pits of the test plate may be colored yellow, due to the tin present, but there should be no darkening due to the presence of copper. If the cathode appears dark, as though tin had been deposited on it, dissolve the coating in 10 cc. of HNO_3, sp. gr. 1.42, filter off the tin as before, add to the filtrate 5 cc. of H_2SO_4, sp. gr. 1.84, and redeposit copper by electrolysis. It is rarely necessary thus to purify the deposited copper.

If zinc is to be determined in the alloy be careful to keep the solution quantitative when the electrodes are removed, catching all washings in the beaker containing the electrolyte.

A slight amount of copper is retained by the metastannic acid (H_2SnO_3), which should be recovered in very accurate work but is generally neglected in routine analysis.

DETERMINATION OF LEAD
BY THE
ELECTROLYTIC METHOD.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)

METHOD.

In a 250-cc. beaker dissolve 5 g. of bronze in 25 cc. o HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. Receive the combined filtrate and washings in a 250-cc. beaker. Dilute to about 150 cc. with distilled water and insert electrodes. In the positive terminal use a sand-blasted platinum gauze electrode such as is used for the cathode in the determination of copper: in the negative terminal insert an electrode such as is used for the anode in the determination of copper. Cover with a pair of split watch glasses and electrolyze. For each solution use a current of 1.25 to 1.5 amperes at 10 volts continued for about one hour. Wash down the cover glasses, electrodes and sides of beaker, raising the level of the liquid slightly, and continue the electrolysis for 15 minutes. If no darkening of the newly exposed surface of the platinum can be detected the lead has been entirely deposited. Continue the electrolysis until no darkening of the platinum can be detected when the current has been passed for 15 minutes after the level of the liquid has been raised.

When the lead has been entirely deposited, remove the anode quickly, rinse it in distilled water and then in alcohol, and dry it at 210° C. for one-half hour. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too high. For exceptionally accurate or investigation work redissolve the coating from the electrode and determine the lead as sulfate. See the "Determination of Lead as Sulfate."

NOTES.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, and traces of tin are sometimes found in the PbO_2 deposit. Small amounts of manganese also are occasionally deposited with the PbO_2. Tin and manganese are rarely present in the PbO_2 in amounts which necessitate a purification of the deposit.

In this and the following method a slight amount of lead may be retained by the H_2SnO_3. This should be recovered in very accurate work, but is neglected in routine analysis.

DETERMINATION OF LEAD

AS

SULFATE.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)

(OPTIONAL.)

SOLUTIONS REQUIRED.

"Lead Acid."—Mix 300 cc. of H_2SO_4, sp. gr. 1.84, and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate, c. p., in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and syphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD.

In a 250-cc. beaker dissolve 5 g. of bronze in 25 cc. of HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate, or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. To the combined filtrate and washings add 120 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. Cool, add 105 cc. of distilled water to dissolve the salts and to make the acid concentration the same as in lead acid, heat to boiling, and allow to cool and settle for 5 hours, or over night if convenient. Filter on a weighed porcelain gooch crucible and wash with lead acid.

Wash out the lead acid with dilute alcohol, set the Gooch crucible inside a porcelain crucible, dry and ignite for 5 minutes at the full heat of a Tirrill burner, cool and weigh as $PbSO_4$, which contains 68.29 per cent lead.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too low.

NOTE.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, but by the preliminary baking and long standing, most of the H_2SnO_3 is precipitated.

DETERMINATION OF COPPER AND LEAD SIMULTANEOUSLY BY THE ELECTROLYTIC METHOD.

(FOR SAMPLES CONTAINING OVER 0.2 PER CENT OF LEAD.)

METHOD.

[In a 150-cc. beaker dissolve 1 g. of bronze in 10 cc. of HNO_3, sp. gr. 1.42. When the action has ceased, evaporate the solution to dryness, and bake thoroughly on the edge of a hot plate. Add 10 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time add 50 cc. of hot distilled water, heat to boiling, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. filter papers, keeping the solution hot, and receive the filtrate in a 200-cc. electrolysis beaker. Wash with boiling hot water, dilute to about 100 cc. and insert electrodes. In the positive terminal insert one of the platinum gauze anodes previously described, and in the negative terminal insert a platinum gauze cathode. Cover with a pair of split watch glasses and electrolyze, using a current of from 3 to 5 amperes at approximately 10 volts for each solution. After about 45 minutes the lead will have been entirely deposited on the anode as PbO_2; without interrupting the current add to the electrolyte 3 to 4 cc. of H_2SO_4, sp. gr. 1.84, and continue the electrolysis. When the solution is colorless, wash down cover glasses, electrodes and sides of beaker, raising the level of the liquid slightly, and continue the passage of the current about 15 minutes, noting whether or not copper is deposited on the newly exposed surface of the platinum. If no copper appears, transfer about 1 cc. of the colorless solution to the cavity of a porcelain test plate, and add a few drops of fresh H_2S water. If the slightest discoloration occurs continue the electrolysis until there is no discoloration whatever upon repeating the test. Remove the solution from the electrodes quickly without interrupting the current. Rinse the electrodes in distilled water and then dip them in two successive baths of alcohol. Dry the anode at 210° C. for one-half hour. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value. Shake off the excess alcohol from the cathode and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

Accuracy.—Duplicate copper determinations should check within 0.10 per cent of copper. Duplicate lead determinations should check within 0.02 per cent of lead. Lead results obtained by this method are likely to be about 0.01 per cent too high. See notes under the "Determination of Lead by the Electrolytic Method."

DETERMINATION OF TIN.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20, and 500 cc. of distilled water.

Dilute Sulfuric Acid.—Mix 300 cc. of H_2SO_4, sp.gr., 1.84, and 600 cc. of distilled water.

Dilute Ammonia.—Mix 100 cc. of NH_4OH, sp. gr. 0.90, and 900 cc. of distilled water.

Ammonium-Acetate Solution for Washing.—Dissolve 10 g. of ammonium acetate in 300 cc. of distilled water. Make slightly acid with acetic acid and saturate with H_2S gas.

METHOD.

In a 150-cc. beaker dissolve 2 g. of bronze in a mixture of 10 cc. of HCl, sp. gr. 1.20, and 5 cc. of HNO_3, sp. gr. 1.42. Dilute to about 75 cc. with distilled water. Add NH_4OH, sp. gr. 0.90, until the basic salts of copper have dissolved and the solution has become a deep blue. Boil and allow to settle, and filter on a closely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute HCl. Dilute the solution to about 100 cc. Add NH_4OH, sp. gr. 0.90, until a permanent precipitate forms.

Heat the solution to boiling, allow to settle, filter and wash as before. Dissolve the precipitate on the filter with boiling hot dilute H_2SO_4, washing the paper very thoroughly with this acid. Add NH_4OH, sp. gr. 0.90, cautiously until the precipitate which forms at first dissolves rather slowly. Allow the solution to stand for some hours and if any lead sulfate forms filter it off. Dilute the solution to about 200 cc. and saturate it with H_2S gas. Filter the precipitated tin sulfide off on double papers and wash with ammonium-acetate solution, retaining the filtrate and washings for the iron determination. Dry the precipitate and place it with the papers in a porcelain crucible which projects part way through a hole in a piece of asbestos board. Heat slowly until any free sulfur has been driven off, but without allowing the sulfur to burn. When the sulfur has been expelled, place the crucible on a triangle and ignite slowly at first and finally at the full heat of the burner. If the precipitate weighs more than 20 mg. heat to constant weight, using a blast lamp. Weigh as SnO_2, which contains 78.81 per cent of tin.

Accuracy.—Duplicate determinations should check within 0.06 per cent of tin.

NOTES.

If, during ignition, the sulfur is allowed to burn, some tin sulfate may be formed, causing high results. On the other hand, low results may be caused by too high heat, which causes spattering and volatilizes some tin sulfide.

Tin and iron are best determined on the same sample, retaining the filtrate from the tin sulfide precipitate to use for the iron determination.

DETERMINATION OF IRON.

SOLUTIONS REQUIRED.

See "Determination of Tin," and the following:

Dilute Sulfuric Acid for Reductor.—Mix 50 cc. of H_2SO_4, sp. gr. 1.84, and 1000 cc. of distilled water. This solution is used boiling hot.

Potassium Permanganate.—Dissolve 0.2 g. of $KMnO_4$ in water, filter through asbestos, and dilute to 1000 cc. with distilled water. Standardize against 0.020-g. portions of pure sodium oxalate. Each cubic centimeter is equivalent to approximately 0.00033 g. of iron.

METHOD.

Proceed exactly as in the "Determination of Tin" through the filtration and washing of the precipitated tin sulfide. Combine the filtrate and washings from the tin sulfide precipitate and boil until all H_2S is expelled. Add HNO_3, sp. gr. 1.42, until the iron is oxidized, which is shown by the solution becoming clear and of a yellowish color. Add about 5g. of NH_4Cl, then NH_4OH, sp. gr. 0.90, until a permanent precipitate forms. Boil, allow to settle, filter on a loosely woven filter paper and wash with dilute ammonia and with hot water. Dissolve the precipitate on the paper with hot dilute HCl and add NH_4OH, sp. gr. 0.90, to the solution again until a permanent precipitate forms. Boil, allow to settle, filter on a loosely woven filter paper, and wash with dilute ammonia and with hot water until all NH_4Cl is removed. Dissolve the precipitate and wash the filter paper with 100 cc. of dilute H_2SO_4 for reductor. Pass the solution through a Jones reductor, wash first with 150 cc. of the H_2SO_4 for reductor and then with 100 cc. of distilled water. Titrate with the standard $KMnO_4$ solution.

Accuracy.—Duplicate determinations should check within 0.03 per cent of iron.

NOTES.

A blank determination should be made on corresponding amounts of acid and water passed through the reductor and the results should be corrected accordingly. About 0.5 cc. of the permanganate will be required to give a permanent coloration to the solution.

A small quantity of liquid should always be left in the reductor funnel, and air should never be allowed to enter the body of the reductor.

For description and further details of use of reductor see "The Chemical Analysis of Iron" by A. A. Blair, or "Quantitative Chemical Analysis" by H. P. Talbot.

DETERMINATION OF MANGANESE
BY THE
PERSULFATE METHOD.

SOLUTIONS REQUIRED.

Solution for Dissolving.—Mix 500 cc. of H_2SO_4, sp. gr. 1.84, 200 cc. of HNO_3, sp. gr. 1.42, and 1700 cc. of distilled water.

Silver Nitrate.—Dissolve 1.33 g. of $AgNO_3$ in 1000 cc. of distilled water.

Stock Sodium Arsenite.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of Na_2CO_3 and 150 cc. of distilled water. Heat the flask and contents on the steam bath until the As_2O_3 is dissolved. Cool the solution, filter and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite.—Mix 200 cc. of stock sodium-arsenite solution with 2500 cc. of distilled water, and standardize against a steel or iron of known manganese content as determined by the Bismuthate Method, or standardize against one of the Bureau of Standards' standard irons or steels. One cc. of this solution should be equivalent to approximately 0.00050 g. of manganese.

Ammonium Persulfate.—Dissolve 60 g. of ammonium persulfate in 1000 cc. of distilled water.

METHOD.

In a 250-cc. Erlenmeyer flask dissolve 1 g. of bronze in 24 cc. of the "solution for dissolving". Allow to stand on a steam bath or hot plate until entirely dissolved, and until the oxides of nitrogen are expelled. Add 15 cc. of $AgNO_3$ solution and 20 cc. of ammonium persulfate and leave on the steam bath until the solution has developed a full permanganate color and no bubbles can be seen to come off when the flask is given a whirling motion. Cool to below 25° C. in running water, and add 50 cc. of cold water. Titrate with standard sodium-arsenite solution to the disappearance of the pink color.

Accuracy.—Duplicate determinations should check within 0.02 per cent of manganese.

NOTES.

Large amounts of permanganic acid are unstable; on that account, samples which contain large amounts of manganese should have correspondingly small samples weighed out. For instance, with metal containing 1.5 per cent of manganese use a 0.10-g. sample, while if metal contains 0.75 per cent manganese use a 0.20-g. sample.

The solution must be cold when it is titrated, for high temperatures cause low results to be obtained.

DETERMINATION OF MANGANESE BY THE BISMUTHATE METHOD.

(OPTIONAL.)

SOLUTIONS REQUIRED.

Nitric Acid (1:3).—Mix 250 cc. of HNO_3, sp. gr. 1.42, and 750 cc. of distilled water.

Nitric Acid for Washing.—Mix 30 cc. of HNO_3, sp. gr. 1.42, and 970 cc. of distilled water.

Ferrous Ammonium Sulfate.—Dissolve 12.4 g. of ferrous ammonium sulfate crystals in 950 cc. of distilled water, and add 50 cc. of H_2SO_4, sp. gr. 1.84.

Potassium Permanganate.—Dissolve 1 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow it to stand for about one week and then filter it through asbestos. Standardize against 0.10-g. portions of pure sodium oxalate.

METHOD.

In a 250-cc. Erlenmeyer flask dissolve 1 g. of bronze in 50 cc. of HNO_3 (1:3). Without filtering off the H_2SnO_3, cool and add 0.5 g. of sodium bismuthate. Heat for a few minutes until the purple color has disappeared, with or without the precipitation of manganese dioxide. Add a little ferrous ammonium sulfate solution until the solution becomes clear, and boil until the oxides of nitrogen are expelled. Cool, add an excess of sodium bismuthate and agitate for a few minutes. Add 50 cc. of HNO_3 for washing and filter through an alundum crucible or an asbestos pad. Wash with 50 cc. of the HNO_3 for washing. Add from a pipette or a burette 10 cc. of ferrous ammonium sulfate solution and titrate with $KMnO_4$. Owing to the presence of considerable copper, the end point is somewhat different from the normal pink color.

In exactly the same manner carry through a blank determination, using the same amounts of HNO_3 and sodium bismuthate as was done with the regular sample. Finally add exactly 10 cc. of ferrous ammonium sulfate solution and titrate with $KMnO_4$. The difference between the two titrations is due to the manganese. Since one manganese as permanganate oxidized five irons, the iron value of the permanganate multiplied by the factor $\frac{Mn}{5\,Fe}$ (or 0.1967) gives the value in terms of manganese.

Accuracy.—Duplicate determinations should check within 0.02 per cent of manganese.

NOTES.

Instead of employing the method of reducing the permanganic acid by means of standardized ferrous ammonium sulfate solution and titrating the excess of this reagent, it is possible to reduce the permanganic acid by standard sodium-arsenite solution. See "Determination of Manganese by the Persulfate Method."

The filtrate from the bismuthate must be perfectly clear, as the least particle of bismuthate carried into the filtrate will vitiate the results.

STANDARD METHODS OF CHEMICAL ANALYSIS
OF
GUN METAL.

Serial Designation: B 28 – 19.

These methods are issued under the fixed designation B 28; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1918; ADOPTED, 1919.

GENERAL CONSIDERATIONS.

Phosphorus should not be present in this alloy except in very small amounts. A rapid qualitative test for it is given whereby it is easily seen whether or not it is necessary to make a correction for its presence in the determination of tin.

A special method is also given for the determination of tin in alloys such as phosphor-bronze which contain considerable phosphorus.

DETERMINATION OF COPPER
BY THE
ELECTROLYTIC METHOD.

APPARATUS FOR ELECTROLYSIS.

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

Anodes.—Platinum anodes may be of the spiral type when used in the determination of copper by electrolysis, or in the electrolytic determination of lead when it is present in amounts not over 0.2 per cent. When used in electrolytic determination of copper and lead together in samples containing 0.2 per cent lead or over, the anodes should be of wire gauze. Spiral anodes should be made from 1.02-mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm. Platinum gauze used in making anodes should contain approximately 400 meshes per sq. cm. (50 meshes per linear inch). The gauze should be formed into closed cylinder-approximately 12 mm. in diameter and 30 mm. in height. The cylinders should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom. The stem should be made from 1.02-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 137 mm., and the gauze should be sand blasted.

METHOD.

In a 150-cc. beaker dissolve 1 g. of gun metal in 10 cc. of HNO_3, sp. gr. 1.42. When the action has ceased, boil until the oxides of nitrogen are expelled, add 50 cc. of hot distilled water, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. ashless papers, being careful to keep the solution hot throughout the process of filtration, and receiving the filtrate in a 200-cc. beaker of the tall type used in electrolysis. Wash with boiling hot water. Retain the papers containing the precipitate for subsequent use in the tin determination.

Add to the filtrate 5 cc. of H_2SO_4, sp. gr. 1.84, and determine copper by electrolysis, retaining the electrolyte, after the removal of the copper, for the subsequent determination of zinc. See the "Determination of Copper by the Electrolytic Method," Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.

Accuracy.—Duplicate determinations should check within 0.10 per cent of copper.

NOTES.

Copper, zinc, and tin are conveniently determined on the same sample, tin being first removed, and any zinc tested for after copper has been deposited by electrolysis.

If the solution becomes cool during the first filtration some of the metastannic acid (H_2SnO_3) may dissolve.

DETERMINATION OF TIN.

(FOR SAMPLES FREE FROM PHOSPHORUS.)

METHOD.

See the "Determination of Copper by the Electrolytic Method."

Use the papers containing the H_2SnO_3 which was filtered off in the Determination of Copper by the Electrolytic Method. Ignite the papers with the precipitate, while moist, in a porcelain or platinum crucible, slowly at first, and finally at the full heat of the burner. If the precipitate weighs more than 20 mg. heat to constant weight, using a blast lamp. Weigh as SnO_2, which contains 78.81 per cent of tin.

Accuracy.—Duplicate determinations should check within 0.04 per cent of tin.

NOTES.

This method is not accurate for alloys which contain arsenic, antimony or phosphorus, or which contain over 0.25 per cent of iron. The SnO_2 may be contaminated with a slight amount of copper and purification is required in very accurate work, but is generally neglected in routine analysis.

The ignited tin oxide contains any phosphorus which may be present in the alloy. The following test is here made use of to detect phosphorus and to estimate its amount, if any is found.

QUALITATIVE TEST FOR PHOSPHORUS.

SOLUTIONS REQUIRED.

Ferric Chloride.—Dissolve 25 g. of ferric chloride in 100 cc. of distilled water, and add 25 cc. of HCl, sp. gr. 1.20.

METHOD.

Dip a small piece of the alloy into a few cubic centimeters of ferric chloride for about 10 seconds, and then rinse it in running water. Alloys containing phosphorus are darkened noticeably where they have been dipped; alloys containing over 0.25 per cent of phosphorus are rendered almost black by this test. Arsenic and antimony act in a manner similar to phosphorus, but should not be present in this alloy.

Correction for Phosphorus.

In alloys containing up to 0.20 per cent of phosphorus a correction for its presence in the ignited tin oxide may be made according to the following empirical method. From the phosphorus content of the alloy, which must be determined on a separate sample, compute the weight of P_2O_5 and subtract two-thirds of this weight from the weight of the ignited tin oxide containing phosphorus. The remainder is considered as pure SnO_2, which contains 78.81 per cent of tin. The factor for converting phosphorus to $\frac{2}{3} \times P_2O_5$ is 152.6 per cent or approximately one and one-half times the phosphorus content of the sample.

If the alloy contains over 0.20 per cent of phosphorus a special method for the determination of tin should be used.

Arsenic and antimony should not be present in weighable amounts in the tin oxide resulting from a sample of gun metal.

Iron may be present in the H_2SnO_3 in very small amounts, but its weight is negligible in this determination.

In alloys which contain over 0.25 per cent of iron, use the method for the "Determination of Tin in Manganese Bronze." Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.

DETERMINATION OF TIN.

(For Samples Containing Phosphorus.)

Solutions Required.

Yellow Ammonium Sulfide.—Saturate 150 cc. of NH_4OH, sp. gr. 0.90, with H_2S gas and then add 50 cc. more NH_4OH. Dissolve in this solution 3 or 4 g. of sulfur flour and about 1 g.

of NH_4Cl. Make up this solution freshly and filter immediately before using.

Dilute Yellow Ammonium Sulfide for Washing.—Mix 20 cc. of yellow ammonium sulfide, prepared as above, and 400 cc. of distilled water.

Ammonium Acetate for Washing.—Dissolve 10 g. of ammonium acetate in 300 cc. of distilled water, make slightly acid with acetic acid and saturate with H_2S gas.

METHOD.

See the "Determination of Copper by the Electrolytic Method."

Use the papers containing the freshly filtered H_2SnO_3 which was filtered off in the Determination of Copper by the Electrolytic Method. Transfer the papers with the precipitate to a 150-cc. beaker, and cover them with 40 to 50 cc. of yellow ammonium sulfide. Warm for about 15 minutes, or until the H_2SnO_3 has dissolved. Filter and wash thoroughly with dilute yellow ammonium sulfide. Acidify the combined filtrate and washings cautiously with 50-per-cent acetic acid. Warm, and allow the precipitated tin sulfide and sulfur to settle. Filter on double papers and wash with ammonium-acetate solution. Dry the precipitate, and place it with the papers in a porcelain crucible which projects part way through a hole in a piece of asbestos board. Heat slowly until the free sulfur has been driven off, but without allowing the sulfur to burn. When the sulfur has been expelled, place the crucible on a triangle and ignite slowly at first, and finally at the full heat of the burner. If the precipitate weighs more than 20 mg., heat to constant weight, using a blast lamp. Weigh as SnO_2, which contains 78.81 per cent of tin.

Accuracy.—Duplicate determinations should check within 0.06 per cent of tin.

NOTES.

If during the first filtration the solution becomes cool, some of the H_2SnO_3 may dissolve.

During ignition, if the sulfur is allowed to burn, some tin sulfate may be formed, causing high results. On the other hand, low results may be caused by too high heat, which causes spattering, and volatilizes some tin sulfide.

DETERMINATION OF LEAD BY THE ELECTROLYTIC METHOD.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)

METHOD.

In a 250-cc. beaker dissolve 5 g. of gun metal in 25 cc. of HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. Receive the combined filtrate and washings in a 250-cc. beaker. Dilute to about 150 cc. with distilled water and insert electrodes. In the positive terminal use a sand-blasted platinum gauze electrode such as is used for the cathode in the determination of copper; in the negative terminal insert an electrode such as is used for the anode in the determination of copper. Cover with a pair of split watch glasses and electrolyze. For each solution use a current of 1.25 to 1.5 amperes at 10 volts continued for about one hour. Wash down the cover glasses, electrodes and sides of beaker, raising the level of the liquid slightly, and continue the electrolysis for 15 minutes. If no darkening of the newly exposed surface of the platinum can be detected the lead has been entirely deposited. Continue the electrolysis until no darkening of the platinum can be detected when the current has been passed for 15 minutes after the level of the liquid has been raised.

When the lead has been entirely deposited, remove the anode quickly, rinse it in distilled water and then in alcohol, and dry it at 210° C. for one-half hour. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too high. For exceptionally accurate or investigation work redissolve the coating from the electrode and determine the lead as sulfate. See the "Determination of Lead as Sulfate."

NOTES.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, and traces of tin are sometimes found in the PbO_2 deposit. Small amounts of manganese also are occasionally deposited with the PbO_2. Tin and manganese are rarely present in the PbO_2 in amounts which necessitate a purification of the deposit.

DETERMINATION OF LEAD
AS
SULFATE.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)
(OPTIONAL.)

SOLUTIONS REQUIRED.

"*Lead Acid.*"—Mix 300 cc. of H_2SO_4, sp. gr. 1.84, and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate, c. p., in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and syphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD.

In a 250-cc. beaker dissolve 5 g. of gun metal in 25 cc. of HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate, or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. To the combined filtrate and washings add 120 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. Cool, add 105 cc. of distilled water to dissolve the salts and to make the acid concentration the same as in lead acid, heat to boiling, and allow to cool and settle for 5 hours, or over night if convenient. Filter on a weighed porcelain Gooch crucible and wash with lead acid. Wash out the lead acid with dilute alcohol, set the Gooch crucible inside a porcelain crucible, dry and ignite for 5 minutes at the full heat of a Tirrill burner, cool and weigh as $PbSO_4$, which contains 68.29 per cent lead.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too low.

NOTE.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, but by the preliminary baking and long standing, most of the H_2SnO_3 is precipitated.

DETERMINATION OF ZINC.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20 and 500 cc. of distilled water.

METHOD.

See the "Determination of Copper by the Electrolytic Method."

After the copper has been completely deposited by electrolysis, quickly remove the cathode and wash it thoroughly in distilled water, catching the washings in the beaker containing the electrolyte. Heat the solution and saturate with H_2S gas. Filter off any precipitate, and boil the solution to expel H_2S. Make the solution barely alkaline with NH_4OH, and add 25 cc. of 85-per-cent formic acid. Dilute the solution with distilled water to 300 cc., heat to boiling, and saturate with H_2S gas. Filter and wash with hot water. Dissolve the precipitate with hot dilute HCl, and transfer the solution to a weighed platinum or porcelain dish or crucible. Add a few drops of H_2SO_4, sp. gr. 1.84, and evaporate the solution until copious fumes escape. If the solution is not clear and colorless, cool, add a few cubic centimeters of HNO_3, sp. gr. 1.42, and again evaporate the solution until fumes of H_2SO_4 come off freely. Repeat the treatment with HNO_3 if necessary, until the organic matter is destroyed, and the solution is colorless. Remove the excess of H_2SO_4 by heating the dish cautiously, and finally heat to dull redness. Weigh as zinc sulfate, which contains 40.49 per cent of zinc.

Accuracy.—Duplicate determinations should check within 0.05 per cent of zinc.

DETERMINATION OF PHOSPHORUS BY THE ALKALIMETRIC METHOD.

SOLUTIONS REQUIRED.

Nitric Acid for Dissolving.—Mix 1000 cc. of HNO_3, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of HNO_3, sp. gr. 1.42, and 1000 cc. of distilled water.

Ammonium Molybdate.

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH, sp. gr. 0.90, filter and add 60 cc. of HNO_3, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of HNO_3, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water and let stand at least 24 hours before using.

Potassium Nitrate, 1-per-cent.—Dissolve 10 g. of KNO_3 in 1000 cc. of distilled water.

Phenolphthalein Indicator.—Dissolve 0.2 g. of phenolphthalein in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium Hydroxide.—Dissolve 6.5 g. of purified NaOH in 1000 cc. of distilled water, add a slight excess of 1-per-cent solution of barium hydroxide, let stand for 24 hours, decant the liquid, and standardize it against a steel of known phosphorus content as determined by the molybdate-magnesia method, so that 1 cc. will be equivalent to 0.01 per cent of phosphorus on the basis of a 2-g. sample (see notes). Protect the solution from carbon dioxide with a soda-lime tube.

Ferric Chloride.—Dissolve 100 g. of ferric chloride (phosphorus free) in 100 cc. of distilled water.

Standard Nitric Acid.—Mix 10 cc. of HNO_3, sp. gr. 1.42, and 1000 cc. of distilled water. Titrate the solution against standardized NaOH, using phenolphthalein as indicator, and make it equivalent to the NaOH by adding distilled water.

METHOD.

In a 400-cc. casserole dissolve 1 g. of gun metal in 10 cc. of HNO_3, sp. gr. 1.42. Add 20 cc. of HCl, sp. gr. 1.20, and evaporate to dryness. Moisten with HCl, evaporate to dryness again, and bake to dull redness. Moisten with HCl again, add 3 cc. of ferric-chloride solution, and dilute to about 200 cc. with distilled water. Add NH_4OH, sp. gr. 0.90, until the basic salts of copper have dissolved and the solution has become a deep blue. Boil, allow to settle, and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute HCl, dilute the solution to about 200 cc., add NH_4OH, sp. gr. 0.90, until the precipitate which forms at first dissolves rather slowly, and saturate with H_2S gas. Filter off and reject the precipitate. Boil the filtrate to expel H_2S, and add HNO_3, sp. gr. 1.42, until the iron is oxidized. Add NH_4OH, sp. gr. 0.90, until the solution is alkaline. Boil and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with HNO_3 for dissolving, receiving the solution in a 350-cc. Erlenmeyer flask. Add NH_4OH, sp. gr. 0.90, until the iron is entirely precipitated, and then add HNO_3, sp. gr. 1.42, cautiously until the solution just becomes clear. Bring the solution to a temperature of about 80° C., and add 40 cc. of ammonium molybdate at room temperature. Allow to stand for one minute, shake or agitate for 3 minutes, and filter on a 9-cm. paper. Wash the precipitate three times with the 2-per-cent HNO_3 solution to free it from iron, and continue the washing with the 1-per-cent KNO_3 solution until the precipitate and flask are free from acid.

Transfer the paper and precipitate to a solution flask, add 20 cc. of distilled water, 5 drops of phenolphthalein solution as indicator, and an excess of standard NaOH solution. Insert a rubber stopper and shake vigorously until solution of the precipitate is complete. Wash off the stopper with distilled water and determine the excess of NaOH solution by titrating with standard HNO_3 solution. Each cubic centimeter of standard NaOH solution represents 0.02 per cent of phosphorus.

Accuracy.—Duplicate determinations should check within 0.01 per cent of phosphorus.

NOTES.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

All distilled water used in titration should be freed from carbon dioxide by boiling or otherwise.

Bureau of Standards Standard Steel No. 19 (*a*) is recommended as a suitable steel for standardization of the NaOH solution.

DETERMINATION OF PHOSPHORUS
BY THE
FERRIC-ALUM METHOD.
(OPTIONAL.)

SOLUTIONS REQUIRED.

Ferric Chloride.—Dissolve 100 g. of ferric chloride (phosphorus free) in 100 cc. of distilled water.

Dilute Ammonia.—Mix 100 cc. of NH_4OH, sp. gr. 0.90, and 900 cc. of distilled water.

Dilute Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20, and 500 cc. of distilled water.

Dilute Sulfuric Acid for Dissolving.—Mix 200 cc. of H_2SO_4, sp. gr. 1.84, and 800 cc. of distilled water.

Dilute Sulfuric Acid for Reductor.—Mix 50 cc. of H_2SO_4, sp. gr. 1.84, and 1000 cc. of distilled water. This solution is used boiling hot.

Ammonium Molybdate.

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH, sp. gr. 0.90, filter and add 60 cc. of HNO_3, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of HNO_3, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly, then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

Acid Ammonium Sulfate.—Mix 25 cc. of H_2SO_4, sp. gr. 1.84, and 1000 cc. of distilled water, and then add 15 cc. of NH_4OH, sp. gr. 0.90.

Ferric Alum.—Dissolve 200 g. of ferric ammonium sulfate crystals in 1950 cc. of distilled water. Add 50 cc. of H_2SO_4, sp. gr. 1.84, and 80 cc. of phosphoric acid, 85 per cent.

Potassium Permanganate.—Dissolve from 3.0 to 3.2 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow the solution to stand for about one week, and then filter it through an asbestos filter. Standardize by using about 0.200-g. portions of pure sodium oxalate.

METHOD.

In a 400-cc. casserole dissolve 1 g. of gun metal in 10 cc. of HNO_3, sp. gr. 1.42. Add 20 cc. of HCl, sp. gr. 1.20, and evaporate to dryness. Moisten with HCl, evaporate to dryness again, and bake to dull redness. Moisten with HCl again, add 3 cc. of ferric chloride solution, and dilute to about 200 cc. with distilled water. Add NH_4OH, sp. gr. 0.90, until the basic salts of copper have dissolved and the solution has become a deep blue. Boil, allow to settle, and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute HCl, dilute the solution to about 200 cc., add NH_4OH, sp. gr. 0.90, until the precipitate which forms at first dissolves rather slowly, and saturate with H_2S gas. Filter off and reject the precipitate. Boil the filtrate to expel H_2S, and add HNO_3, sp. gr. 1.42, until the iron is oxidized. Add NH_4OH, sp. gr. 0.90, until the solution is alkaline. Boil and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute H_2SO_4, receiving the solution in a 350-cc. Erlenmeyer flask. Add NH_4OH, sp. gr. 0.90, until the iron is entirely precipitated, and then add HNO_3, sp. gr. 1.42, cautiously until the solution just becomes clear. Bring the solution to a temperature of about 80° C., and add 40 cc. of ammonium molybdate at room temperature. Allow to stand for one minute, shake or agitate for 3 minutes, filter on a 9-cm. paper, and wash very thoroughly (about 25 times) with acid ammonium sulfate. Dissolve the precipitate on the paper using 50 cc. of dilute ammonia. Add sufficient H_2SO_4 to adjust the acidity to 2.5 per cent by volume, and immediately pass the solution through a Jones reductor, which has the reductor tube prolonged and reaching nearly to the bottom of the flask, dipping into 50 cc. of ferric-alum solution. Wash through the reductor with 150 cc. of the H_2SO_4 for reductor and follow with 100 cc. of distilled water. Titrate with the standard $KMnO_4$ solution.

By this method the molybdenum which in passing through the reductor has been reduced entirely to the form corresponding to the oxide Mo_2O_3, is partially oxidized by the ferric alum, an equivalent amount of iron being reduced to the ferrous condition. The resultant solution is not rapidly oxidized through contact with air during the titration, and the calculations can therefore be made on the Mo_2O_3—$2MoO_3$ basis.

Accuracy.—Duplicate determinations should check within 0.01 per cent of phosphorus.

NOTES.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

A blank determination should be made on corresponding amounts of acid and water, passing through the reductor into the usual amount of ferric-alum solution in the flask.

A small quantity of liquid should always be left in the reductor funnel, and air should never be allowed to enter the reductor.

For description and further details of the use of reductor see "Chemical Analysis of Iron" by A. A. Blair, or "Quantitative Chemical Analysis" by H. P. Talbot.

STANDARD SPECIFICATIONS AND TESTS
FOR
PORTLAND CEMENT.

Serial Designation: C 9 – 21.

These specifications and tests are issued under the fixed designation C 9; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1908, 1909, 1916, 1920 (EFFECTIVE JAN. 1, 1921).

These specifications were approved January 15, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

SPECIFICATIONS.

Definition. 1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

I. CHEMICAL PROPERTIES.

Chemical Limits. 2. The following limits shall not be exceeded:

Loss on ignition, per cent	4.00	
Insoluble residue, per cent	0.85	.75
Sulfuric anhydride (SO_3), per cent	2.00	
Magnesia (MgO), per cent	5.00	4.00

II. PHYSICAL PROPERTIES.

Specific Gravity. 3. The specific gravity of cement shall be not less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific gravity test will not be made unless specifically ordered.

Fineness. 4. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

Soundness. 5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of Setting. 6. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile Strength. 7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see Section 50) composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at Test, days.	Storage of Briquettes.	Tensile Strength lb. per sq. in.
7	1 day in moist air, 6 days in water..................................	200
28	1 day in moist air 27 days in water.................................	300

8. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

III. PACKAGES, MARKING AND STORAGE.

Packages and Marking. 9. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 lb. net. A barrel shall contain 376 lb. net.

Storage. 10. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

IV. INSPECTION.

Inspection. 11. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

V. REJECTION.

Rejection. 12. The cement may be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

TESTS.

VI. SAMPLING.

Number of Samples.

16. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 lb.

17. (*a*) *Individual Sample.*—If sampled in cars one test sample shall be taken from each 50 bbl. or fraction thereof. If sampled in bins one sample shall be taken from each 100 bbl.

(*b*) *Composite Sample.*—If sampled in cars one sample shall be taken from one sack in each 40 sacks (or 1 bbl. in each 10 bbl.) and combined to form one test sample. If sampled in bins or warehouses one test sample shall represent not more than 200 bbl.

Method of Sampling.

18. Cement may be sampled at the mill by any of the following methods that may be practicable, as ordered:

(*a*) *From the Conveyor Delivering to the Bin.*—At least 8 lb. of cement shall be taken from approximately each 100 bbl. passing over the conveyor.

(*b*) *From Filled Bins by Means of Proper Sampling Tubes.*—Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 ft. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) *From Filled Bins at Points of Discharge.*—Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

Treatment of Sample.

19. Samples preferably shall be shipped and stored in airtight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample, break up lumps and remove foreign materials.

VII. CHEMICAL ANALYSIS.

LOSS ON IGNITION.

Method. 20. One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25-cc. capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any temperature between 900 and 1000° C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

Permissible Variation. 21. A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 4 per cent.

INSOLUBLE RESIDUE.

Method. 22. To a 1-g. sample of cement shall be added 10 cc. of water and 5 cc. of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 cc. and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete. The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 cc. of a 5-per-cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1 : 9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue.

Permissible Variation. 23. A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 0.85 per cent.

SULFURIC ANHYDRIDE.

Method. 24. One gram of the cement shall be dissolved in 5 cc. of concentrated hydrochloric acid diluted with 5 cc. of water, with gentle warming; when solution is complete 40 cc. of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 cc., heated to boiling and 10 cc. of a hot 10-per-cent solution of barium chloride shall be added slowly, drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulfate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulfuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulfuric anhydride instead of using a separate sample.

Permissible Variation. 25. A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 2.00 per cent.

MAGNESIA.

Method. 26. To 0.5 g. of the cement in an evaporating dish shall be added 10 cc. of water to prevent lumping and then 10 cc. of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration the residue may be heated to 150 or even 200° C. for one-half to one hour. The residue shall be treated with 10 cc. of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered and the solution digested for ten minutes on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water.[1] Five cubic centimeters of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese which may be present, shall be added to the filtrate (about 250 cc.). This shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 cc. of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 cc., and the second precipitate shall be collected and washed on the filter used in the first instance if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 cc. of ammonium hydroxide shall be added, the solution brought to boiling, 25 cc. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after one hour shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition it shall be redissolved in hydrochloric acid and the solution diluted to 100 cc. Ammonia shall be added in slight excess, and the liquid boiled. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand until settled, filtered and washed. The combined filtrates from the calcium precipitates shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 cc., and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 cc. of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall be set aside for several hours in a cool place, filtered and washed with water containing 2.5 per cent of NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 cc., 1 cc. of a saturated solution of sodium-ammonium-hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about two hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

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[1] Since this procedure does not involve the determination of silica, a second evaporation is unnecessary.

Permissible Variation. 27. A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 5.00 per cent.

VIII. DETERMINATION OF SPECIFIC GRAVITY.

Apparatus. 28. The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 1. This apparatus is standardized by the U. S. Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baumé, shall be used in making this determination.

Method. 29. The flask shall be filled with either of these liquids to a point on the stem between zero and one cubic centimeter, and 64 g. of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 g. of the cement.

The specific gravity shall then be obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (cc.)}}$$

30. The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0°.5 C. The results of repeated tests should agree within 0.01.

31. The determination of specific gravity shall be made on the cement as received; if it falls below 3.10, a second determination shall be made after igniting the sample as described in Section 20.

IX. DETERMINATION OF FINENESS.

32. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames not less than 1½ in. below the top of the frame. The sieve frames shall be circular, approximately 8 in. in diameter, and may be provided with a pan and cover. **Apparatus.**

33. A standard No. 200 sieve is one having nominally an 0.0029-in. opening and 200 wires per inch standardized by the U. S. Bureau of Standards, and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 in. in width. The diameter of the wire should be 0.0021 in. and the average diameter shall not be outside the limits 0.0019 to 0.0023 in. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similarly graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

34. The test shall be made with 50 g. of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g. passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample. **Method.**

35. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in Section 34.

X. MIXING CEMENT PASTES AND MORTARS.

36. The quantity of dry material to be mixed at one time shall not exceed 1000 g. nor be less than 500 g. The propor- **Method.**

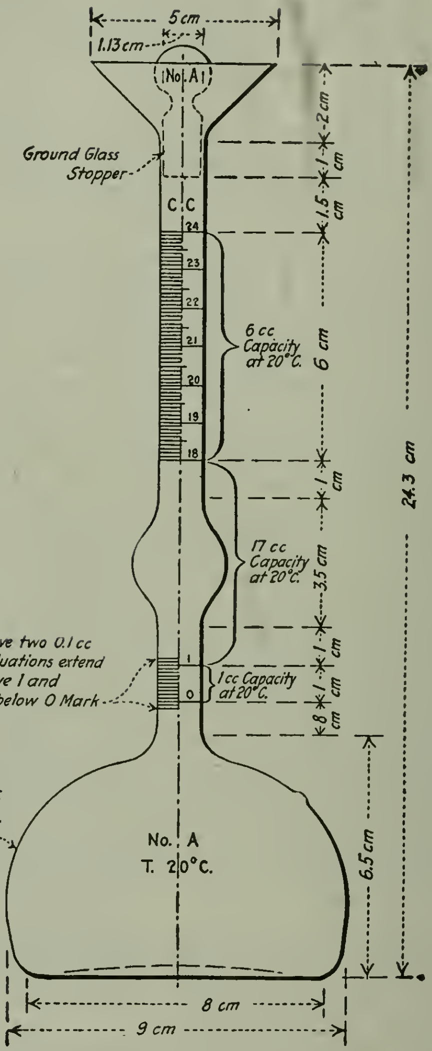

FIG. 1.—Le Chatelier Apparatus.

tions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 cc. of water = 1 g.). The dry materials shall be weighed, placed upon a non-absorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of ½ minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute.[1] During the operation of mixing, the hands should be protected by rubber gloves.

37. The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21° C. (70° F.).

XI. NORMAL CONSISTENCY.

Apparatus. 38. The Vicat apparatus consists of a frame *A* (Fig. 2) bearing a movable rod *B*, weighing 300 g., one end *C* being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle *D*, 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw *E*, and has midway between the ends a mark *F* which moves under a scale (graduated to millimeters) attached to the frame *A*. The paste is held in a conical, hard-rubber ring *G*, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate *H* about 10 cm. square.

Method. 39. In making the determination, 500 g. of cement, with a measured quantity of water, shall be kneaded into a paste, as described in Section 36, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in ½ minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

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[1] In order to secure uniformity in the results of tests for the time of setting and tensile strength the manner of mixing above described should be carefully followed. At least one minute is necessary to obtain the desired plasticity which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing should be on the side of over mixing.

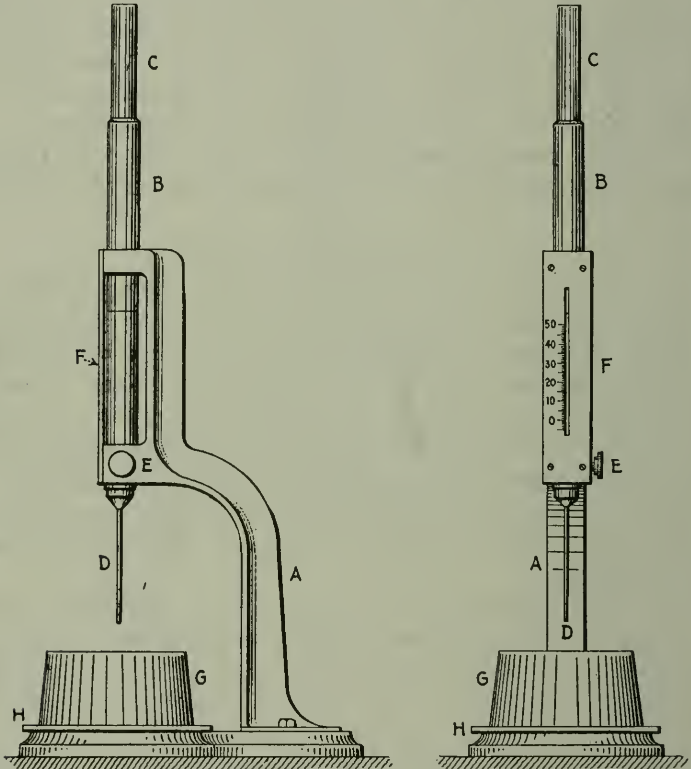

FIG. 2.—Vicat Apparatus.

40. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal con-

sistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in Table I, the values being in percentage of the combined dry weights of the cement and standard sand.

XII. DETERMINATION OF SOUNDNESS.[1]

41. A steam apparatus, which can be maintained at a temperature between 98 and 100° C., or one similar to that shown in Fig. 3, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position. **Apparatus.**

TABLE I.—PERCENTAGE OF WATER FOR STANDARD MORTARS.

Percentage of Water for Neat Cement Paste of Normal Consistency.	Percentage of Water for One Cement, Three Standard Ottawa Sand.	Percentage of Water for Neat Cement Paste of Normal Consistency.	Percentage of Water for One Cement, Three Standard Ottawa Sand.
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

Method. 42. A pat from cement paste of normal consistency about 3 in. in diameter, $\frac{1}{2}$ in. thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 in. square, and stored in moist air for 24 hours. In molding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

43. The pat shall then be placed in an atmosphere of steam at a temperature between 98 and 100° C. upon a suitable support 1 in. above boiling water for 5 hours.

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[1] Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking or disintegration.

Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours and are not an indication of unsoundness. These conditions are illustrated in Fig. 4.

The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.

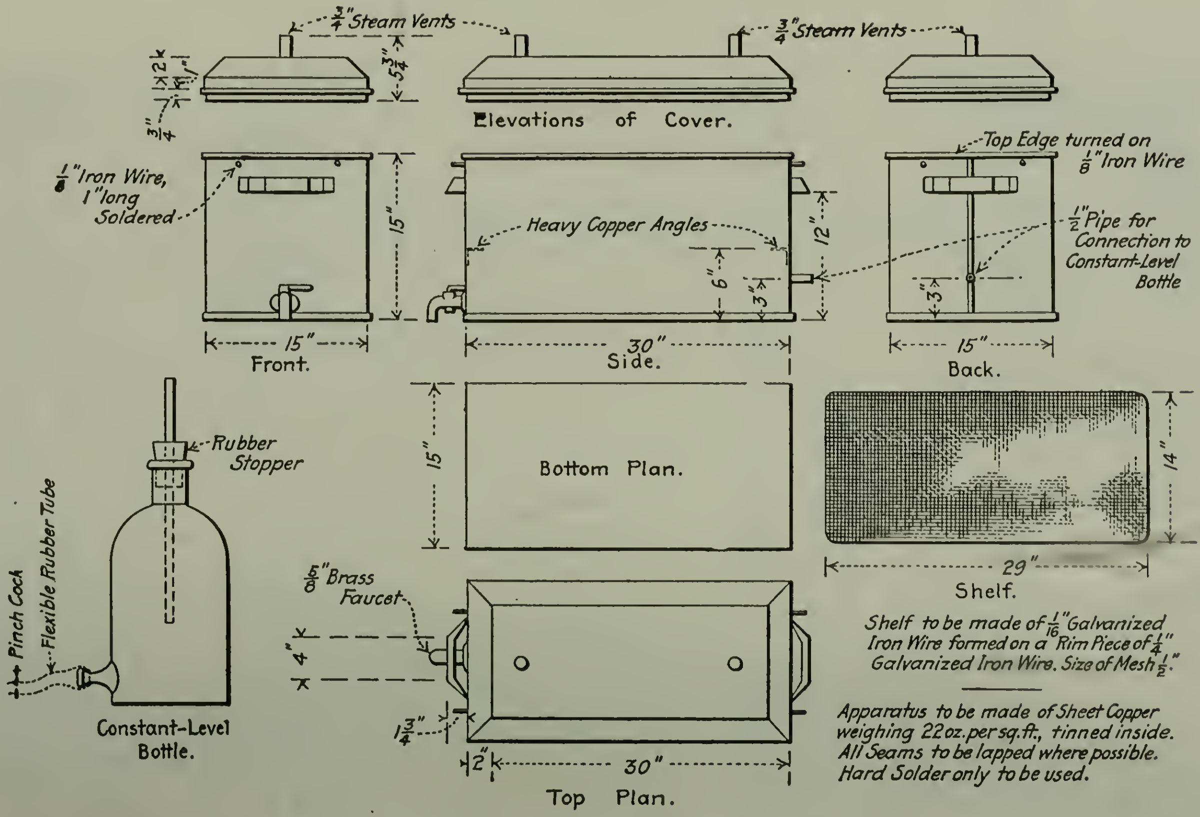
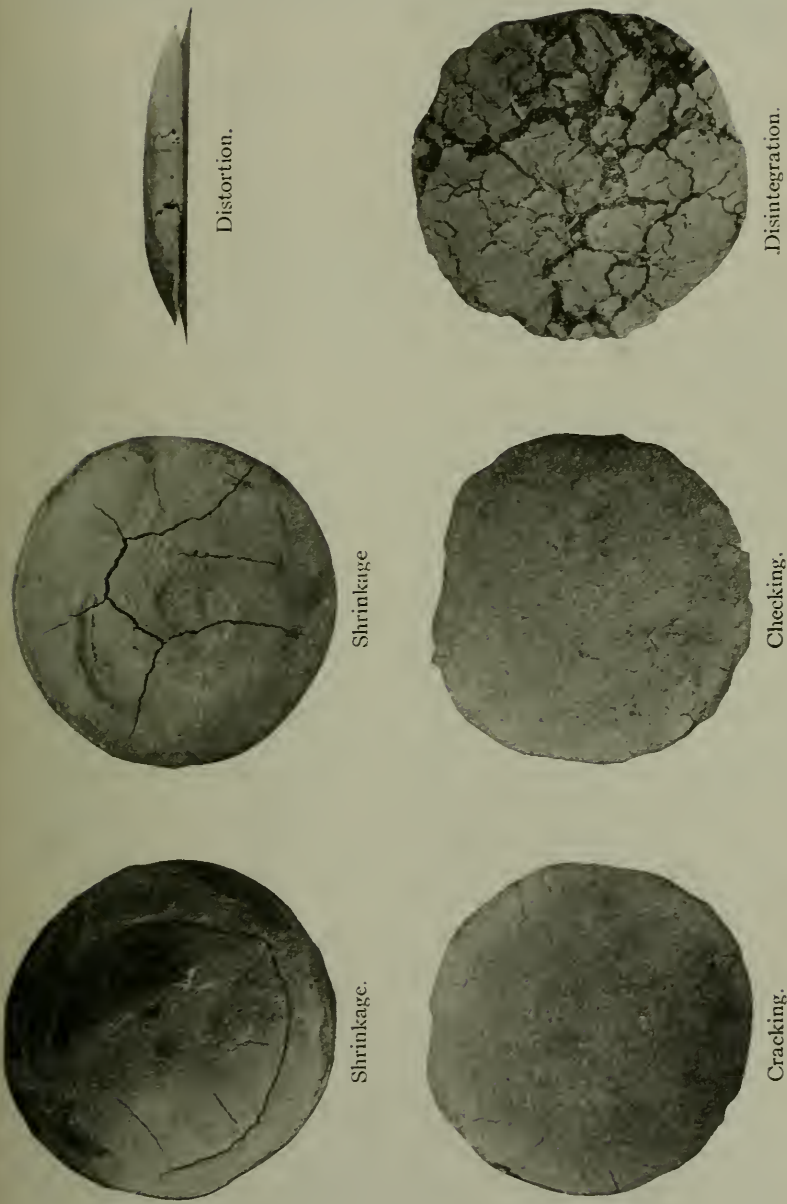

$\frac{3}{4}$" Steam Vents
$\frac{3}{4}$" Steam Vents
2
1"
$\frac{3}{4}$"
$5\frac{3}{4}$"
Elevations of Cover.
$\frac{1}{8}$" Iron Wire, 1" long Soldered
15"
15"
Front.
Heavy Copper Angles
12"
6"
3"
30"
Side.
Top Edge turned on $\frac{1}{8}$" Iron Wire
$\frac{1}{2}$" Pipe for Connection to Constant-Level Bottle
3"
15"
Back.
Rubber Stopper
Pinch Cock
Flexible Rubber Tube
Constant-Level Bottle.
15"
Bottom Plan.
14"
29"
Shelf.
$\frac{5}{8}$" Brass Faucet
4"
$1\frac{3}{4}$"
2"
30"
Top Plan.
Shelf to be made of $\frac{1}{16}$" Galvanized Iron Wire formed on a Rim Piece of $\frac{1}{4}$" Galvanized Iron Wire. Size of Mesh $\frac{1}{2}$".
Apparatus to be made of Sheet Copper weighing 22 oz. per sq. ft., tinned inside. All Seams to be lapped where possible. Hard Solder only to be used.

FIG. 3.—Apparatus for Making Soundness Test of Cement.



Shrinkage.

Shrinkage

Distortion.

Cracking.

Checking.

Disintegration.

FIG. 4.—Typical Failures in Soundness Test.

44. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

XIII. DETERMINATION OF TIME OF SETTING.

45. The following are alternate methods, either of which may be used as ordered:

Vicat Apparatus. 46. The time of setting shall be determined with the Vicat apparatus described in Section 38. (See Fig. 2.)

Vicat Method. 47. A paste of normal consistency shall be molded in the hard-rubber ring *G* as described in Section 39, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in ½ minute after being released; and the final set, when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.

Gillmore Needles. 48. The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 5 (*b*).

Gillmore Method. 49. The time of setting shall be determined as follows: A pat of neat cement paste about 3 in. in diameter and ½ in. in thickness with a flat top (Fig. 5 (*a*)), mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C. (70° F.). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle $\frac{1}{12}$ in. in diameter, loaded to weigh ¼ lb. The final set has been acquired when the pat will bear without appreciable indentation, the Gillmore needle $\frac{1}{24}$ in. in diameter, loaded to weigh 1 lb. In making the test, the needles shall be held in a vertical position and applied lightly to the surface of the pat.

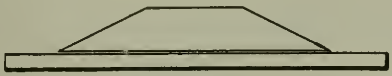
XIV. TENSION TESTS.

Form of Test Piece.

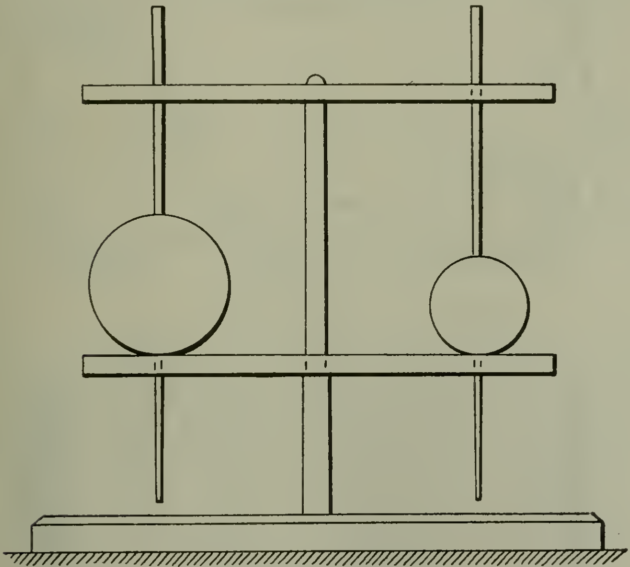
50. The form of test piece shown in Fig. 6 shall be used. The molds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in Fig. 7. Molds shall be wiped with an oily cloth before using.

Standard Sand.

51. The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Co., at a cost of three cents per pound, f. o. b. cars, Ottawa, Ill.



(*a*) Pat with Top Surface Flattened for Determining Time of Setting by Gillmore Method.



(*b*) Gillmore Needles.

FIG. 5.

52. This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 g. pass the No. 30 sieve after one minute continuous sieving of a 500-g. sample.

53. The sieves shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 in. and the average diameter shall not be outside the limits of 0.0160 and 0.0170 in.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31 5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 in. and the average diameter shall not be outside the limits 0.0105 to 0.0115 in.

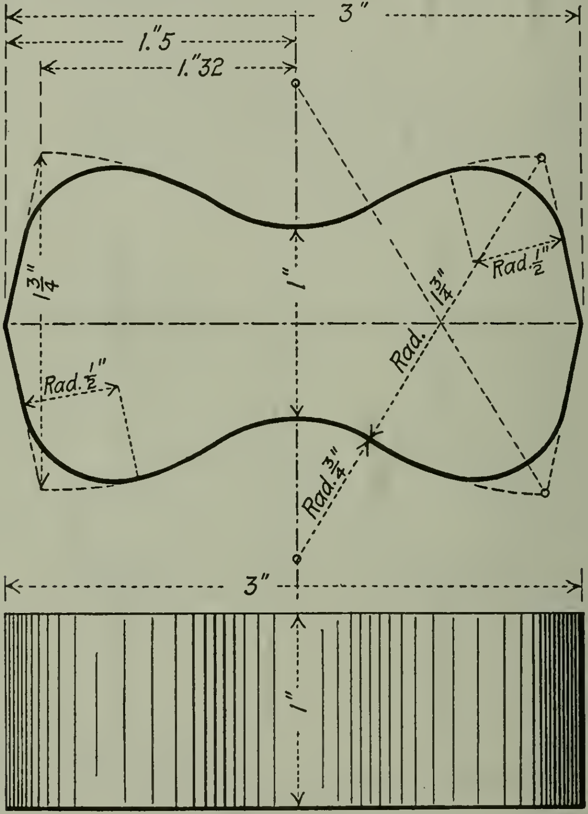


FIG. 6.—Details for Briquette.

Molding. 54. Immediately after mixing, the standard mortar shall be placed in the molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing and smoothing off repeated.

Testing. 55. Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centered and the load applied continuously at the rate of 600 lb. per minute.

56. Testing machines should be frequently calibrated in order to determine their accuracy.

Faulty Briquettes. 57. Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

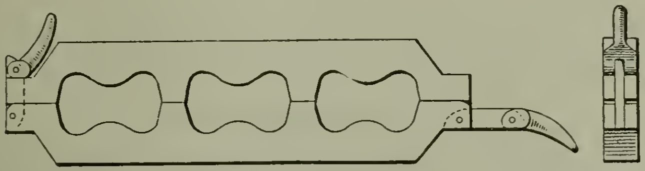


FIG. 7.—Gang Mold.

XV. STORAGE OF TEST PIECES.

Apparatus. 58. The moist closet may consist of a soapstone, slate or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with non-absorbent shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

Methods. 59. Unless otherwise specified all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hours.

60. The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of non-corroding material.

61. The air and water shall be maintained as nearly as practicable at a temperature of 21° C. (70° F.).

STANDARD SPECIFICATIONS
FOR
NATURAL CEMENT.

Serial Designation: C 10-09.

These specifications are issued under the fixed designation C 10; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1908, 1909.

Definition. 1. Natural cement is the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

I. PHYSICAL PROPERTIES.

Fineness. 2. The residue on a standard No. 100 sieve shall not exceed 10 per cent, and on a standard No. 200 sieve shall not exceed 30 per cent, by weight.

Soundness. 3. Pats of neat cement about 3 in. in diameter, $\frac{1}{2}$ in. thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*) A pat shall then be kept in air at normal temperature.

(*b*) Another pat shall be kept in water maintained as near 70° F. as practicable.

These pats shall be observed at intervals for at least 28 days, and, to satisfactorily pass the tests, shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegrating.

Time of Setting. 4. The cement shall not develop initial set in less than 10 minutes, using the Vicat needle. Final set shall be attained in not less than 30 minutes nor more than 3 hours, using the Vicat needle.

Tensile Strength. 5. The minimum requirements for tensile strength for briquettes 1 sq. in. in cross-section shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

AGE.	STRENGTH.
Neat Cement.	
24 hours in moist air	75 lb.
7 days (1 day in moist air, 6 days in water)	150 "
28 days (1 " " " 27 " ")	250 "
One Part Cement, Three Parts Standard Ottawa Sand.	
7 days (1 day in moist air, 6 days in water)	50 lb.
28 days (1 " " " 27 " ")	125 "

II. PACKAGES, MARKING AND STORAGE.

Packages and Marking. 6. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon. A bag shall contain 94 lb. net. A barrel shall contain 282 lb. net.

Storage. 7. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

III. INSPECTION.

Inspection. 8. (*a*) Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test.

(*b*) The cement shall be tested in accordance with the methods contained in the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials.

IV. REJECTION.

Rejection. 9. The cement may be rejected if it fails to meet any of the requirements of these specifications.

10. Cement failing to meet the 7-day requirements may be held awaiting the results of the 28-day tests before rejection.

EDITORIAL NOTE.

In connection with its reports on the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9), Committee C-1 on Cement has declared its purpose to give consideration to the revision of the present Standard Specifications for Natural Cement, and recommended that in the meantime the methods of tests for Portland cement be applied to the testing of natural cement. In this connection attention is directed to the following feature:

Fineness.—The Standard Specifications for Natural Cement specify a standard No. 100 sieve (see Section 2), which is not included in the Standard Specifications and Tests for Portland cement. The requirements for the standard No. 100 sieve will therefore remain as published in the 1915 Year-Book, page 358, as follows:

Diameter of Wire, in.		0.0042 – 0.0048
Meshes per Linear Inch	Warp	95 – 101
	Woof	93 – 103

STANDARD SPECIFICATIONS
FOR
DRAIN TILE.

Serial Designation: C 4 – 21.

These specifications are issued under the fixed designation C 4; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1916, 1921.

Classes.

1. (*a*) These specifications cover three classes of drain tile, namely, Farm Drain Tile, Standard Drain Tile, and Extra-Quality Drain Tile.

(*b*) The purposes for which these classes are intended to be suitable are as follows:

Farm Drain Tile, for ordinary private drainage work on farms, for moderate sizes and depths;

Standard Drain Tile, for ordinary district land drainage at moderate depths;

Extra-Quality Drain Tile, for district land drainage, for considerable depths and where an extra quality is desired.

Basis of Purchase.

2. The purchaser shall specify the class or classes of tile to be supplied, whether Farm Drain Tile, Standard Drain Tile, or Extra-Quality Drain Tile. Standard Drain Tile shall be supplied where no other advance selection is stated.

Basis of Acceptance.

3. (*a*) The acceptability of drain tile shall be determined (1) by the results of the chemical and physical tests hereinafter specified, and (2) by visual inspection, to determine whether the tiles comply with the specifications as to dimensions, shape, and freedom from visible external and internal defects.

(*b*) The acceptance of drain tile as satisfactorily meeting one of these two general requirements shall not be construed as in any way waiving the other.

I. MATERIALS AND MANUFACTURE.

Materials.

4. (*a*) These specifications shall apply to drain tile made of shale, fire clays or surface clays and to drain tile made of concrete.

(*b*) By *shale*[1] is meant a stratified clay, usually red-burning, more or less indurated by heat or pressure, with well-marked cleavage, laid down prior to the present geological epoch.

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[1] Definitions of the terms shale, fire clay, and surface clay, and of clays in general as applied to refractories, are now under consideration by Committee E-8 on Nomenclature and Definitions, in cooperation with the several standing committees interested.—ED.

(*c*) By *fire clay*[1] is meant a stratified clay, usually buff-burning, usually less indurated than shales, with poorly marked cleavage, laid down prior to the present geological epoch.

(*d*) By *surface clay*[1] is meant an unstratified, unconsolidated plastic glacial or alluvial clay, laid down by the glacial ice sheet, or on the flood plains of rivers, during the present geological epoch.

(*e*) By concrete is meant a suitable mixture of Portland cement, mineral aggregates and water, hardened by hydraulic chemical reaction.

(*f*) If the purchaser desires to exclude any of these materials he shall so specify in advance, All materials used shall be first-class of their kind and suitable for the purpose.

Manufacture.

5. The method of manufacture shall be such as to insure excellence of product and uniformity in quality.

II. CHEMICAL TESTS AND REQUIREMENTS.

Chemical Tests and Requirements.

6. The purchaser may specify special chemical requirements as to resistance of the tile to chemical action in cases where soils or drainage waters have marked acid or alkaline character, or are of abnormally high temperature, and may prescribe chemical tests of the tile to ascertain whether these special requirements are met. Without a special agreement in advance, no drain tile shall be rejected by reason of its composition as determined by ultimate chemical analysis.

The presence in drain tile of visible grains or masses of caustic lime, iron pyrites, or any other minerals which are known to cause slaking or disintegration of the tile, shall be construed as a valid ground for rejection, unless satisfactory proof be submitted that the tiles are permanent and durable, and that the objectionable minerals are not present in quantity or condition to work damage.

III. PHYSICAL TESTS.

Physical Tests.

7. The physical tests of drain tile shall include (*A*) Strength Tests and (*B*) Absorption Tests; and may include (*C*) Freezing and Thawing Tests, when specified by the purchaser in advance, or when called for by the manufacturer or other seller as provided in Sections 34, 35, 47 and 52.

Selection of Specimens of Tile.

8. The specimens of tile shall all be selected at the factory or at the shipping destination, or at the trench, at the

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[1] Definitions of the terms shale, fire clay, and surface clay, and of clays in general as applied to refractories, are now under consideration by Committee E-8 on Nomenclature and Definitions, in cooperation with the several standing committees interested.—ED.

option of the purchaser. The selection shall be made by a competent inspector employed by the purchaser. The inspector shall divide the tile into sub-classes if lack of uniformity in any important particular warrants such division, and shall select enough representative specimens of tile from each subclass for a complete set of standard physical tests.

Number and Cost of Specimens of Tile.

9. A standard physical test shall comprise tests of five individual tiles. Specimens of tile may be selected by the inspector in such number as he judges necessary to determine fairly the quality of all the tile. The manufacturer or other seller shall furnish specimens of tile without separate charge up to 0.5 per cent of the whole number of tile, and the purchaser shall pay for all in excess of that percentage at the same rate as for other tile.

(*A*) *Strength Tests of Drain Tile.*

Specimens of Tile.

10. The specimens of tile shall be unbroken, full-size tile.

Moisture Condition of Specimens of Tile.

11. The walls of the tile shall, at the time of testing, be as thoroughly wet as will result from completely covering with hay, cloth, or similar absorbent material, and keeping the covering wet for not less than 12 hours.

Temperature Condition of Specimens of Tile.

12. No specimen of tile shall be exposed to water or air temperatures lower than 40° F. from the beginning of wetting until tested. Frozen tile shall be completely thawed before the wetting begins.

Weighing.

13. Each specimen of tile shall be weighed on reliable scales just prior to testing, and the weights shall be reported.

Application of Load.

14. Any machine or hand method which will apply the load continuously, or in increments not exceeding 5 per cent of the estimated total breaking load, may be used in making the test. The tile shall not be allowed to stand under load longer than is required for observing and recording the loads. All solid parts of the bearing frames and bearing blocks shall be so rigid that the distribution of the load will not be affected appreciably by the deformation of any part. All bearings and the specimens of tile shall be so accurately centered as to secure a symmetrical distribution of the loading on each side of the center of the tile in every direction.

Choice of Bearings.

15. The purchaser shall choose (1) sand bearings, (2) hydraulic bearings, or (3) three-point bearings, for use in making strength tests of drain tile. (See Sections 18, 19, and 20).

Calculation and Reporting of Test Results.

16. The test results shall be calculated and reported, in pounds per linear foot of tile, in terms of the "Ordinary Supporting Strength."[1]

The ordinary supporting strength shall be calculated by multiplying the test breaking loads by the following factors: For sand bearings, 1.00; for hydraulic bearings, 1.25; for three-point bearings, 1.50.

The results of the strength tests shall be reported separately for each of the five individual specimens of tile constituting a standard test, together with the average.

Modulus of Rupture.

17. The modulus of rupture may or may not be calculated and reported, at the option of the purchaser. When reported it shall be calculated by the equations[2]

$$M = 0.20\, r \frac{W}{12} \qquad (1)$$

$$f = \frac{6M}{t^2} \qquad (2)$$

where M = maximum bending moment in wall in pound-inches per inch of length, r = radius of middle line of tile wall in inches, W = ordinary supporting strength, calculated as prescribed in Section 16, in pounds per linear foot of tile, f = modulus of rupture in pounds per square inch, and t = thickness of tile wall in inches.

Five-eighths of the weight of the tile per linear foot for sand bearings, or three-fourths for hydraulic or three-point bearings, shall be added to W in computing the maximum bending moment M, when such addition exceeds 5 per cent of W. The value of t used shall be the average thickness of the wall at the top of the tile or that at the bottom, selecting the lesser of the two.

Sand Bearings.

18. (See Fig. 1.)—When sand bearings are used, the ends of each specimen of tile shall be accurately marked in quarters of the circumference prior to the test. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the tile measured on the middle line of the wall. The depth of bedding above and below the tile at the thinnest points shall be one-half the radius of the middle line of the wall.

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[1] The "ordinary supporting strength," when calculated as specified in Section 16, is approximately equal to the actual supporting strength of a tile when laid in a ditch by the "ordinary" method. See note under Table II.

[2] The coefficient of 0.20 in equation (1) approximates the value found by theoretical analysis and also that determined by extended tests.

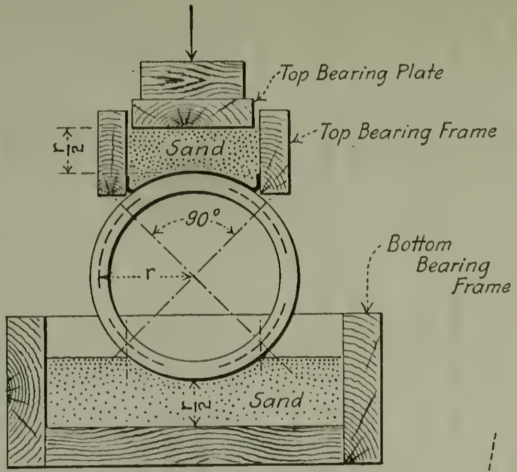
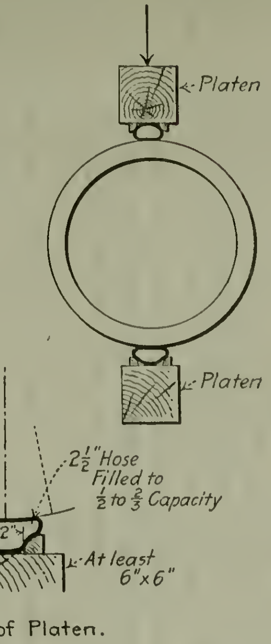
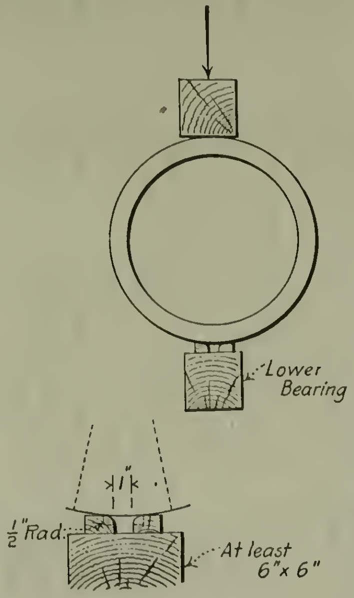


FIG. 1.—Sand Bearings.



Detail of Platen.

FIG. 2.—Hydraulic Bearings.



Detail of Lower Bearing.

FIG. 3.—Three-Point Bearings.

The sand used shall be clean, and shall be such as will pass a No. 4 screen.

The top bearing frame shall not be allowed to come in contact with the tile nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, in such a manner as to permit free motion of the plate in all directions. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weight shall be piled symmetrically about a vertical line through the center of the tile, and that the platform shall not be allowed to touch the top bearing frame.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of the sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the tile during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the tile.

Hydraulic Bearings.

19. (See Fig. 2.)—When hydraulic bearings are used, the ends of each specimen of tile shall be accurately marked in halves of the circumference prior to the test.

An hydraulic bearing shall be composed of a wooden platen, to which is attached, as hereinafter described, a section of rubber hose. The hose shall lie against the tile, and the pressure shall be applied to the hose through the platen.

The platen shall be built of strong wood, and shall be not less than 6 by 6 in. in section, and its least length shall be the length of the tile plus 8 in. One-inch quarter rounds, with their convex surfaces facing and 2 in. apart in the clear, shall be firmly attached to the bearing side. The straight portion of this face shall extend at least the length of the tile, and the platen beyond this length may be cut to the arc of a circle.

Between the quarter rounds shall be laid a piece of $2\frac{1}{2}$-in. hose which shall be closed in a water-tight manner at each end by clamps. The hose shall contain a volume of water not less than one-half nor more than two-thirds its capacity, when completely distended. This hose may be attached to the platen at either end in any satisfactory manner which will not induce wrinkling when under test pressure.

The test load shall be applied at the middle of the top bearing, in such a way as to leave the bearing free to move in the vertical plane of the axis of the tile.

It is recommended that stops be screwed to the platen, symmetrical with the point of application of the load, and at a distance apart not greater than the length of the tile plus ½ in. This will help center the load coming upon the tile.

Three-point Bearings.

20. (See Fig. 3.)—When three-point bearings are used the ends of each specimen of tile shall be accurately marked in halves of the circumference prior to the test.

The lower bearings shall consist of two wooden strips with vertical sides, each strip having its interior top corner rounded to a radius of approximately ½ in. They shall be straight, and shall be securely fastened to a rigid block with their interior vertical sides 1 in. apart.

The upper bearing shall be a wooden block, straight and true from end to end.

The test load shall be applied through the upper bearing block in such a way as to leave the bearing free to move in a vertical plane passing midway between the lower bearings.

In testing a tile which is "out of straight," the lines of the bearings chosen shall be from those which appear to give most favorable conditions for fair bearings.

(B) *Absorption Tests of Drain Tile.*

Test Specimens.

21. Not less than three separate test specimens from each of five separate tiles shall be taken as a "standard sample" for the absorption test. Of the three specimens from each tile, one shall be taken from one end, another from the opposite end, and the third shall be taken from the middle portion of the tile. Each specimen shall be of from 12 to 20 sq. in. in area, measured upon the exterior or convex side, and shall be as nearly square as the nature of the material will readily permit. The specimens shall be obtained by breaking the tile, and shall be apparently sound, solid pieces of the wall of the tile, and shall not show cracks or fissures or shattered edges due to the

shock of breaking or cutting. The specimens may be obtained from the broken pieces of the tiles used in the strength test, if the restrictions as to the size and location of the specimens can be duly observed. The specimens shall be so marked as to permit the identity of each one to be ascertained at any stage of the test.

Drying Test. Specimens.

22. Preparatory to the absorption test, all specimens shall be first weighed and then dried in a drier or oven, at a temperature of not less than 110° C. (230° F.) for not less than three hours. After removal from the drier, the specimens shall be allowed to cool to a temperature of 20 to 25° C. (68 to 77° F.) and reweighed. If the specimens were apparently dry when taken, and the second weight closely checks the first, the specimens shall be considered dry. If the specimens were known to be wet when taken, they shall be placed in the drier for a further drying treatment of two hours, and reweighed. If the third weight checks the second, the specimens shall be considered dry. In case of any doubt, the specimens must be redried for two-hour periods until check weights are obtained.

Weighing and Reweighing.

23. The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same order of accuracy must be obtained.

In reweighing after immersion, the specimens shall be removed from the water, not allowed to drain for more than one minute, the superficial water removed by towel or blotting paper, and the specimens at once put upon the balance.

Immersion of Test Specimens.

24. Specimens after weighing shall be placed in a suitable woven-wire receptacle, packed tightly enough to prevent jostling, covered with distilled water or rainwater, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of 10 to 15° C. (50 to 59° F.).

Calculation and Reporting of Results.

25. The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each individual specimen, together with the mean of the fifteen or more specimens comprising the standard sample, the maximum and the minimum single observations entering into the mean, and the variation between the maximum and the minimum of the three specimens of each tile represented in the the standard sample.

(C) *Freezing and Thawing Tests of Drain Tile.*

Test Specimens. 26. The test specimens employed in making the freezing and thawing test shall be another set selected as specified in Section 21.

Drying Test Specimens. 27. The specimens shall be dried as specified in Section 22.

Weighing and Reweighing. 28. The same scales and weights as are specified in Section 23 for the absorption test or others of equivalent sensitiveness and accuracy shall be employed for the weighings required in the freezing and thawing test. The same procedure in weighings and reweighing as specified in Section 23 shall be used.

Immersion of Test Specimens 29. The specimens shall be immersed for 72 hours in water having a temperature of 18 to 24° C. (65 to 75° F.) and then weighed as specified in Section 23.

Freezing and Thawing. 30. When the specimens (either from the absorption test or from a specially prepared series) have been weighed after saturation with water, they shall be returned to the water, and kept immersed till the freezing test is begun. For freezing, they shall be placed with their concave faces upward in water-tight metal trays, suitably mounted in a rigid metal crate,[1] and immersed in ice water until the specimens have attained substantially the temperature of the water, after which the water shall be drawn down to a depth of $\frac{1}{2}$ in. in each tray. The crate shall then be lifted as a whole, without disturbing the specimens, and placed in the freezing apparatus.

Freezing shall be performed in a quiet atmosphere, free from perceptible natural or artificial currents. If artificial freezing apparatus is employed,[2] the apparatus shall have sufficient heat-absorbent capacity to enable the temperature of the freezing chamber to be brought to $-10°$ C. ($+14°$ F.) or below, within thirty minutes after the introduction of the specimens. The temperature in the freezing apparatus shall not fall lower than $-20°$ C. ($-4°$ F.). The freezing shall be continued until the water in the trays is frozen solid. Exposure to freezing conditions in excess of this requirement shall be considered as without significance.

At the conclusion of freezing under the specified conditions, the crate of specimens shall be withdrawn and at once immersed in water at a temperature of 18 to 24° C. (65 to 75° F.)

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[1] Fig. 4 shows a crate and trays suitable for use in the box for artificial freezing illustrated in Plate I.

[2] Artificial freezing will generally be necessary. It may be conducted in a commercial zero (F.) refrigerating room, or in an artificial freezing box similar to the one shown in Plate I in which zero (F.) temperatures can readily be produced by the use of salt and ice.

in a special receptacle of proper size. Heating shall be continued so that the water will regain the required temperature as soon as practicable after the specimens are immersed. A temperature of 18 to 24° C. (65 to 75° F. shall then be maintained for not less than 2 hours. At the conclusion of the thawing treatment, the crate of specimens shall be inspected and the condition of each sample after each thawing shall be noted in the records.

Method of Determining Failure in Freezing and Thawing Tests.

31. Failure under the freezing and thawing treatment shall be considered to be reached when:

(*a*) The specimens show superficial disintegration or spalling with loss of weight of more than 5 per cent of the initial dry weight; or,

(*b*) The specimens are badly cracked in other than lamination planes; or,

(*c*) The specimens show evident serious loss of structural strength.

IV. PHYSICAL TEST REQUIREMENTS.

Physical Test Requirements.

32. The physical test requirements for the different classes of drain tile shall be as given in Table I.

Absorption Requirements for Drain Tile made of Mixed Clays.

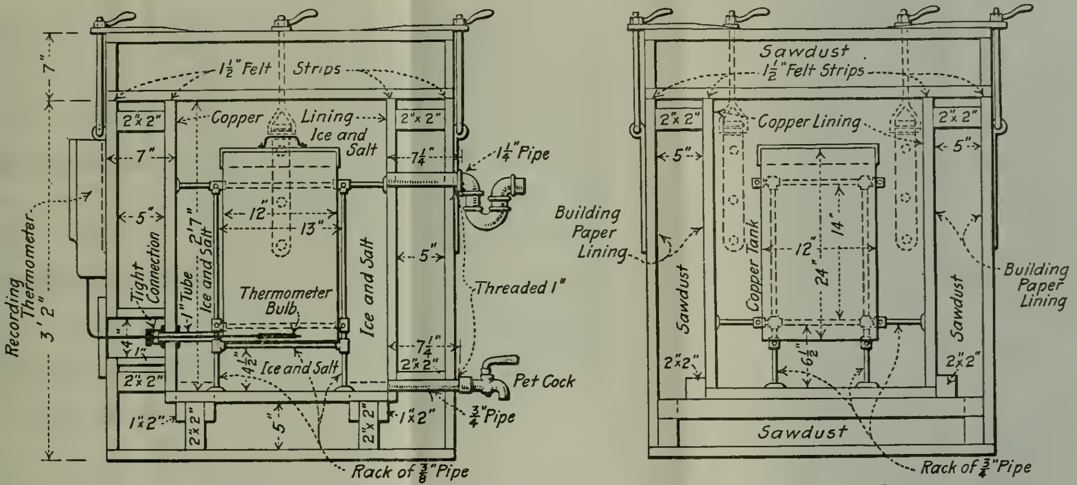
33. Drain tile made of mixtures of surface clays with other clays shall conform to the absorption requirements for surface-clay tile in Table I, when the proportion of surface clay is 75 per cent or more, and to the requirements for shale and fire-clay tile for all other proportions.

Appeal from Absorption Test to Freezing and Thawing Test.

34. In the event that a standard sample (Section 21) of tile fails to meet the requirements of the absorption test, the manufacturer or other seller may demand recourse to the freezing and thawing test, to be made at his expense. In such recourse, the number of tiles tested shall be four times the number represented by the standard sample (Section 21). If the material passes the freezing and thawing test satisfactorily, it shall not be rejected on account of its failure to meet the absorption requirements specified in Table I, but the average percentage of absorption of the specimens used in the freezing and thawing test shall be adopted as the maximum allowable mean absorption for the contract in question.

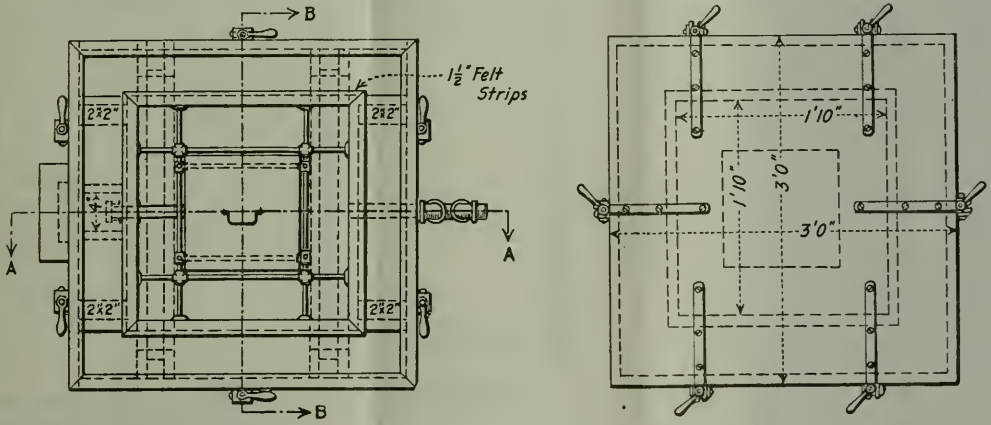
Limits of Fluctuation of Individual Test Specimens in Physical Tests; Culling and Retesting when Limits Exceeded.

35. In the strength tests, individual tiles of a standard test whose mean strength is satisfactory may fall 25 per cent below the requirement for the average without causing rejection. In the absorption test, the absorption of individual tiles of a standard sample (Section 21), which gives a satisfactory mean



Section A-A.

Section B-B

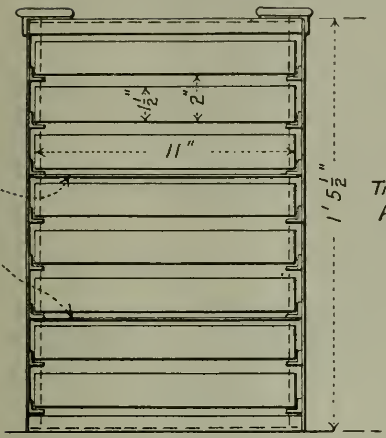


Plan View,
Top Removed.

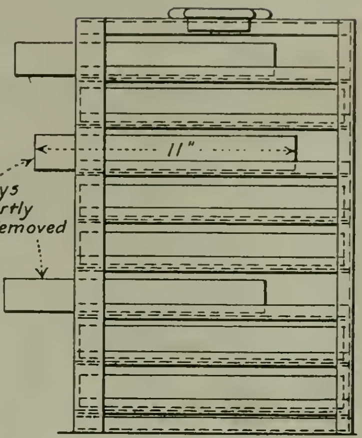
Plan View, Top in Place

SUGGESTED PLANS
FOR
FREEZING BOX
USING SALT AND ICE TO FREEZE

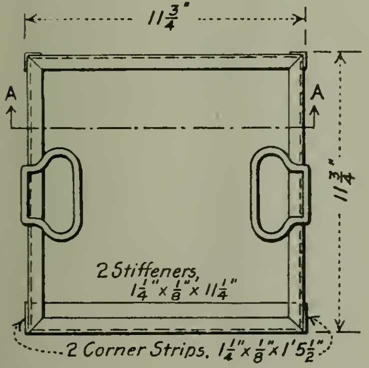
Note: *Box to be Constructed of Seasoned White Pine, free from Defects, or other Suitable Timber, 1"x 6", unless otherwise Specified.*



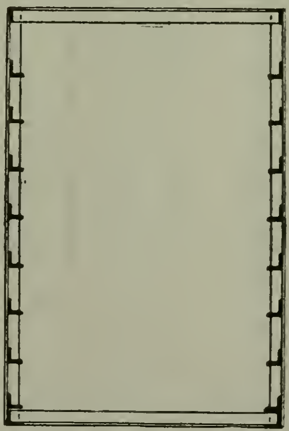
Front Elevation.



Side Elevation.


11 3/4"
A
A
11 3/4"
2 Stiffeners, 1 1/4" x 1/8" x 11 1/4"
2 Corner Strips. 1 1/4" x 1/8" x 1' 5 1/2"

Top View,
Trays Removed.



Section A-A,
Trays Removed.

Notes:

Rack Constructed of 5/8" x 5/8" x 1/8" Galvanized Angles, except as Noted.

All Connections Riveted or Soldered.

Trays, 11" x 11" x 1 1/2" outside, Made of No. 17 Galvanized Steel.

FIG. 4.—Suggested Plans for Freezing Crate and Trays.

absorption percentage, may exceed the average by 25 per cent without causing rejection. In the freezing and thawing test, at least 95 per cent of all the tiles tested shall meet the requirement.

In the event of the failure of a standard sample (Sections 9, 21 and 26) to meet the above requirements, the manufacturer or other seller may thoroughly cull the material and submit a portion for retest at his own expense, and for such retest the number of tiles per sample shall be 10 for the strength and absorption tests and 20 for the freezing and thawing test. In the event of the failure of the material after culling to pass the requirements, it shall be rejected without further test.

TABLE I.—PHYSICAL-TEST REQUIREMENTS FOR DIFFERENT CLASSES OF DRAIN TILE.

Internal Diameter of Tile, in.	Farm Drain Tile.				Standard Drain Tile.				Extra-Quality Drain Tile.			
	Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent.			Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent.			Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent.		
		Shale and Fire-Clay Tile.	Surface-Clay Tile.	Concrete Tile.		Shale and Fire-Clay Tile.	Surface-Clay Tile.	Concrete Tile.		Shale and Fire-Clay Tile.	Surface-Clay Tile.	Concrete Tile.
4	800	11	14	12	1200	9	13	11	1600	7	11	10
6	800	11	14	12	1200	9	13	11	1600	7	11	10
8	800	11	14	12	1200	9	13	11	1600	7	11	10
10	800	11	14	12	1200	9	13	11	1600	7	11	10
12	800	11	14	12	1200	9	13	11	1600	7	11	10
14	900	11	14	12	1200	9	13	11	1600	7	11	10
16	1000	11	14	12	1300	9	13	11	1600	7	11	10
18	(Not Permitted)	(Not Permitted)	(Not Permitted)	(Not Permitted)	1400	9	13	11	1800	7	11	10
20					1500	9	13	11	2000	7	11	10
22					1600	9	13	11	2200	7	11	10
24					1700	9	13	11	2400	7	11	10
26					1800	9	13	11	2600	7	11	10
28					1900	9	13	11	2800	7	11	10
30					2000	9	13	11	3000	7	11	10
32					2100	9	13	11	3200	7	11	10
34					2200	9	13	11	3400	7	11	10
36					2300	9	13	11	3600	7	11	10
38					2400	9	13	11	3800	7	11	10
40					2500	9	13	11	4000	7	11	10
42					2600	9	13	11	4200	7	11	10

NOTE.—When the freezing and thawing test is made as provided in Section 7, the number of freezings and thawings to be endured shall be as follows: For farm drain tile, 24; for standard drain tile, 36; for extra-quality drain tile, 48.

TABLE II.—STANDARD ORDINARY SUPPORTING STRENGTHS OF DRAIN TILE FOR ORDINARY SAND AND FOR THOROUGHLY WET CLAY DITCH FILLING MATERIALS.

STRENGTHS IN POUNDS PER LINEAR FOOT.

Height of Fill above Top of Tile, ft.	Breadth of Ditch at Top of Tile.																			
	1 ft.				2 ft.				3 ft.				4 ft.				5 ft.			
	Method of Laying Pipe.				Method of Laying Pipe.				Method of Laying Pipe.				Method of Laying Pipe.				Method of Laying Pipe.			
	Ordinary.		First Class.		Ordinary.		First Class.		Ordinary.		First Class.		Ordinary.		First Class.		Ordinary.		First Class.	
	Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.	
	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.
2	265	280	220	235	615	635	510	530	970	990	810	830	1 330	1 350	1 110	1 130	1 690	1 710	1 410	1 430
4	400	450	335	375	1 050	1 120	880	935	1 750	1 820	1 460	1 520	2 450	2 540	2 040	2 110	3 160	3 250	2 640	2 710
6	470	545	390	455	1 370	1 500	1 140	1 250	2 370	2 530	1 980	2 110	3 410	3 580	2 840	2 980	4 460	4 640	3 720	3 870
8	505	605	420	505	1 600	1 790	1 330	1 490	2 870	3 110	2 390	2 590	4 220	4 490	3 510	3 740	5 590	5 890	4 660	4 910
10	525	640	440	535	1 760	2 010	1 470	1 680	3 270	3 610	2 730	3 010	4 900	5 290	4 080	4 410	6 590	7 020	5 490	5 850
12	535	660	445	550	1 880	2 190	1 570	1 820	3 600	4 030	3 000	3 355	5 480	6 000	4 570	5 000	7 460	8 030	6 220	6 690
14	540	675	450	560	1 960	2 320	1 640	1 930	3 850	4 380	3 210	3 650	5 980	6 620	4 980	5 520	8 230	8 950	6 850	7 460
16	545	680	455	565	2 030	2 420	1 690	2 020	4 060	4 670	3 390	3 890	6 400	7 160	5 330	5 970	8 890	9 770	7 410	8 150
18	545	685	455	570	2 070	2 500	1 720	2 090	4 230	4 920	3 530	4 100	6 750	7 630	5 630	6 360	9 480	10 520	7 900	8 770
20	545	690	455	575	2 100	2 560	1 750	2 140	4 370	5 130	3 640	4 280	7 050	8 060	5 880	6 720	9 990	11 200	8 330	9 330
22	545	690	455	575	2 120	2 610	1 770	2 180	4 470	5 310	3 730	4 420	7 310	8 430	6 090	7 020	10 400	11 800	8 700	9 830
24	545	690	455	575	2 140	2 650	1 780	2 210	4 560	5 450	3 800	4 540	7 520	8 750	6 270	7 290	10 800	12 300	9 030	10 300
26	545	690	455	575	2 150	2 670	1 790	2 230	4 630	5 580	3 850	4 640	7 700	9 030	6 420	7 530	11 200	12 800	9 320	10 700
28	545	690	455	575	2 160	2 700	1 800	2 250	4 680	5 680	3 900	4 740	7 860	9 280	6 550	7 740	11 500	13 300	9 570	11 100
30	545	690	455	575	2 170	2 710	1 810	2 260	4 730	5 770	3 940	4 810	7 990	9 600	6 660	7 920	11 800	13 700	9 800	11 400
Very great...	545	690	455	575	2 180	2 770	1 820	2 310	4 910	6 230	4 090	5 190	8 730	11 100	7 270	9 230	13 600	17 300	11 400	14 400

NOTE.—Ordinary Pipe Laying is pipe laying in accordance with customary good practice in tile-drain construction, whereby the underside of the pipe is well bedded on soil or 60 to 90 deg. of the circumference.

First-Class Pipe Laying is pipe laying in accordance with the best customary practice in pipe-sewer construction, whereby the entire underside of the pipe is very thoroughly bedded on soil and the entire pipe is surrounded by well-compacted soil, under the direction of an inspector constantly present on the work.

When pipe is laid in a Concrete or Other Permanent Masonry Cradle, strong enough to carry the entire load to the sub-base without breaking and large enough to prevent material settlement, the standard strengths for all dimensions of ditches and all filling materials shall be those specified for Standard Drain Tile in Table 1.

Strength Test Requirements when Manufacturer is held Responsible for Cracking in Ditches.

36. The manufacturer or other seller shall not be held responsible for cracking of drain tile in ditches unless by special agreement in advance, and in any event his obligation shall be held to be discharged by the delivery of drain tile having the minimum ordinary supporting strengths specified in Table II; and, if it is not otherwise specified in advance by the purchaser, tile shall be supplied of the strengths specified for clay ditch filling, for "ordinary" pipe laying and for widths of ditch at the level of the top of the tile equal to 0.5 ft. greater than the outside diameters of the tile. The purchaser shall furnish to the manufacturer or other seller complete information, in advance of receiving bids, as to the number of linear feet of drain tile of each diameter required for each different depth of ditch, measured to the nearest foot from the surface of the ground to the top of the tile.

V. VISUAL INSPECTION.

Visual Inspection and its Purposes.

37. All drain tile shall be given a thorough visual inspection at the trench by a competent inspector employed by the purchaser. The purposes of the visual inspection shall be: (1) to cull and reject imperfect individual tiles; and (2) to determine whether the tiles, independently of meeting the chemical and the physical test requirements, comply with the specifications of general properties, especially as stated hereinafter.

Shape.

38. All drain tile shall be of approximately circular cross-section, except when otherwise specified in advance. They shall be approximately straight, except in the case of special connections. The ends shall be so regular and smooth as readily to admit of making close joints by turning and pressing together adjoining tile.

Nominal Sizes.

39. The sizes of drain tile shall be designated by their interior diameters.

Minimum Lengths.

40. Drain tile smaller than 12 in. in diameter shall have a minimum length of 12 in. Tile of from 12 to 30 in. in diameter, inclusive, shall have lengths not less than the diameters. Tile larger than 30 in. in diameter shall have a minimum length of 30 in.

Structure.

41. Drain tile shall be substantially uniform in structure throughout, and the inspector shall investigate this property by examining fractured surfaces.

Ring.

42. Drain tile shall give a clear ring when stood on end and while dry tapped with a light hammer.

43. The inspector may use the color of drain tile as a general guide in sorting and inspecting, but he shall first so familiarize himself with the raw materials and the processes used in the manufacture of the particular tile in question as to be competent to interpret the true meaning of variations in their color. **Color.**

44. Drain tile shall be reasonably smooth on the inside. **Inside Smoothness.**

45. Drain tile shall be free from cracks and checks extending into the body of the tile in such a manner as to decrease the strength appreciably. Tile shall not be chipped or broken in such a manner as to decrease their strength materially or to admit earth into the drain. **Cracks, Checks, Chips and Broken Pieces.**

46. All drain tile shall be sufficiently "vitrified" or "hard-burned" to afford the degree of supporting strength, percentage of absorption, and resistance to freezing and thawing specified in the physical test requirements prescribed in Table I. **Use of the Terms Vitrified and Hard-Burned.**

TABLE III.—DISTINCTIVE GENERAL PHYSICAL PROPERTIES OF DIFFERENT CLASSES OF DRAIN TILE.

Physical Properties Specified.	Farm Drain Tile.	Standard Drain Tile.	Extra-Quality Drain Tile.
Allowable variation of average diameter below specified diameter, per cent....................................	5	3	3
Allowable variation between maximum and minimum diameters of same tile, or average diameters of adjoining tile, percentage of thickness of wall....................	85	75	65
Allowable variation from straightness, percentage of length.	5	3	3
Allowable thickness of exterior blisters, lumps and flakes which do not weaken tile and are few in number, percentage of thickness of wall..........................	25	20	15
Allowable diameters of above blisters, lumps and flakes, percentage of internal diameter......................	20	15	10
General Inspection....................................	Careful.	Rigid.	Very rigid.

47. The manufacturer or other seller may appeal from decisions of the inspector on questions of strength or structure when such decisions are based on visual inspection alone, in which case the point at issue shall be determined by standard physical tests, the cost of which shall be paid by the appellant, if the inspector was right, or by the purchaser if his inspector was in error. **Appeal from results of Visual Inspection.**

48. Drain tile of the different classes shall, in addition to all requirements heretofore specified. nave the distinctive physical characteristic prescribed in Table III. **Additional Distinctive Physical Characteristics.**

VI. TESTING, INSPECTION AND REJECTION

Making and Reporting Tests. 49. All tests shall be made by experts employed by the purchaser. Full reports of all tests shall be furnished the manufacturer or other seller on his request. Tests shall be made and reported promptly.

Expense of Making Tests. 50. The purchaser shall pay the expense of making all tests except as otherwise specified in Sections 9, 34, 35, 47 and 52.

Number of Tests. 51. The number of standard tests to be made shall be determined by the purchaser.

General Tests and Inspection at Factory. 52. In all contracts for ten or more carloads of tile, preliminary general tests and inspection shall be made at the factory by the purchaser upon demand of the manufacturer or other seller. The expense of such tests and inspection shall be paid by the manufacturer or other seller.

Inspector. 53. The inspector shall be employed by the purchaser.

Inspection. 54. The manufacturer or other seller of the drain tile shall afford the inspector all reasonable facilities for his work, both as to the selection of specimens for tests, and as to visual inspection. Inspection shall be completed promptly.

Rejection. 55. The inspector shall plainly mark all drain tile which he rejects, and such rejected tile shall be removed promptly by the manufacturer or other seller. Upon request of the purchaser, the manufacturer or other seller shall give full account of the removal of rejected tile.

STANDARD SPECIFICATIONS
FOR
PAVING BRICK.

Serial Designation: C 7-15.

These specifications are issued under the fixed designation C 7; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1915.

The quality and acceptability of paving brick, in the absence of other special tests mutually agreed upon in advance by the seller on the one side and the buyer on the other side shall be determined by the following procedure:

I. *The Rattler Test,* for the purpose of determining whether the material as a whole possesses to a sufficient degree strength, toughness and hardness.

II. *Visual Inspection,* for the purpose of determining whether the physical properties of the material as to dimensions, accuracy and uniformity of shape and color, are in general satisfactory, and for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

I. THE RATTLER TEST.

THE SELECTION OF SAMPLES FOR TEST.

1. *Place of Sampling.*—In general, where a shipment of bricks involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, or on cars at their destination or on the street, when delivered ready for use. When the quantity under consideration exceeds 100,000 the sampling shall be done at the factory prior to shipment. Bricks accepted as the result of test prior to shipment, shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Part II, Visual Inspection.

2. *Method of Selecting Samples.*—In general, the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be rejected by visual inspection as provided in Part II, except that where controversy arises, whole tests may be selected to determine the admissibility of certain types or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

3. *Number of Samples per Lot.*—In general, one sample of ten bricks shall be tested for every 10,000 bricks contained in the lot under consideration; but where the total quantity exceeds 100,000, the number of samples tested may be fewer than one per 10,000, provided that they shall be distributed as uniformly as practicable over the entire lot.

4. *Shipment of Samples.*—Samples which must be transported long distances by freight or express shall be carefully put up in packages holding not more than twelve bricks each. When more than six bricks are shipped in one package, it shall be so arranged as to carry two parallel rows of bricks side by side, and these rows shall be separated by a partition. In event of some of the bricks being cracked or broken in transit, the sample shall be disqualified if there are not remaining ten sound undamaged bricks.

5. *Storage and Care of Samples.*—Samples shall be carefully handled to avoid breakage or injury. They shall be kept in the dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100° F. before testing.

THE CONSTRUCTION OF THE RATTLER.

6. *General Design.*—The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame, and driving mechanism as herein described.

Accompanying these specifications is a complete drawing of a rattler which will meet the requirements, and to which reference should be made (Plate II).

7. *The Barrel.*—The barrel of the machine shall be made up of the heads, headliners, staves and stave-liners.

The heads may be cast in one piece with the trunnions, which shall be $2\frac{1}{2}$ in. in diameter, and shall have a bearing 6 in. in length, or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$-in. shafts, and shall be keyseated for two keys, each $\frac{1}{2}$ by $\frac{3}{8}$ in. and spaced 90 deg. apart. The shaft shall be a snug fit and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ in. in the head for the driving end of the rattler, and $11\frac{3}{8}$ in. for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ in.

The heads shall be not less than $\frac{3}{4}$ in. thick, nor more than $\frac{7}{8}$ in. thick. In outline, each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ in. in diameter. Each head shall be provided with flanges not less than $\frac{3}{4}$ in. thick and extending outward $2\frac{1}{2}$ in. from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head shall be smooth and give a true and uniform bearing for the staves. To secure the desired true and uniform bearing the surfaces of the flanges of the head shall be either ground or machined. The flanges shall be slotted on the outer edge, so as to provide for two $\frac{3}{4}$-in. bolts at each end of each stave, said slots to be $\frac{13}{16}$ in. wide and $2\frac{3}{4}$ in., center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace $\frac{3}{8}$ in. thick, extending down the outward side of the head not less than 2 in.

There shall be for each head a cast-iron headliner 1 in. in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ in. in diameter. This headliner shall be fastened to the head by seven $\frac{5}{8}$-in. cap-screws, through the head from the outside. Whenever these headliners become worn down $\frac{1}{2}$ in. below their initial surface level at any point of their surface, they shall be replaced with new ones. The metal of these headliners shall be hard machinery iron and should contain not less than one per cent of combined carbon.

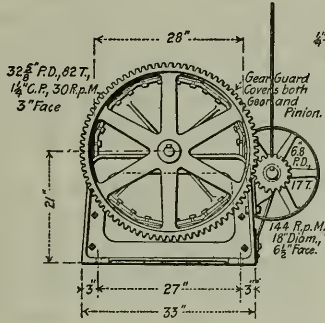
The staves shall be made of 6-in. medium-steel structural channels, 27¼ in. long and weighing 15.5 lb. per lineal foot. The staves shall have two holes 13/16 in. in diameter, drilled in each end, the center line of the holes being 1 in. from the end and 1⅜ in. either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but shall not exceed 5/16 in.

The interior or flat side of each stave shall be protected by a liner ⅜ in. thick by 5½ in. wide by 19¾ in. long. The liner shall consist of medium-steel plate, and shall be riveted to the channel by three ½-in. rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 in. from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once re-riveted.

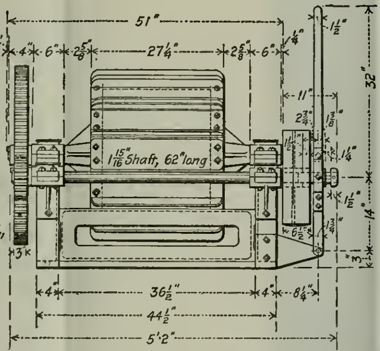
Any test at the expiration of which a stave-liner is found detached from the stave or seriously out of position shall be rejected. When a new rattler, in which a complete set of new staves is furnished, is first put into operation, it shall be charged with 400 lb. of shot of the same sizes, and in the same proportions as provided in Section 9, and shall then be run for 18,000 revolutions at the usual prescribed rate of speed. The shot shall then be removed and a standard shot charge inserted, after which the rattler may be charged with brick for a test.

No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time in such a way that of each pair, one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive but not contiguous; for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative condition of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of new lined staves was placed in position.

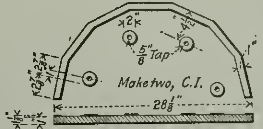
The staves when bolted to the heads shall form a barrel 20 in. long, inside measurement, between head liners. The liners of the staves shall be so placed as to drop between the head-liners. The staves shall be bolted tightly to the heads by four ¾-in. bolts, and each bolt shall be provided with a lock nut,



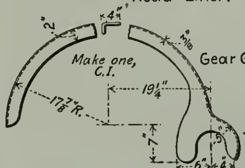
End Elevation.



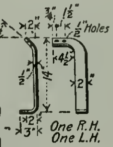
Side Elevation.



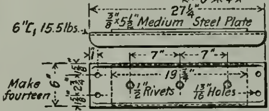
Head Liner.



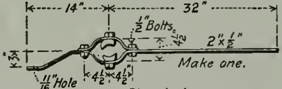
Gear Guard.



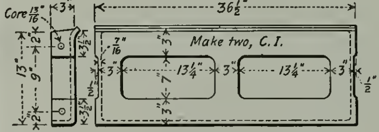
Supports for Guard.



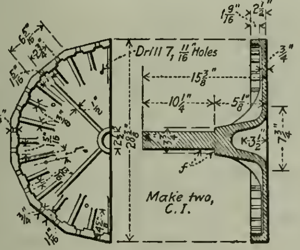
Stave.



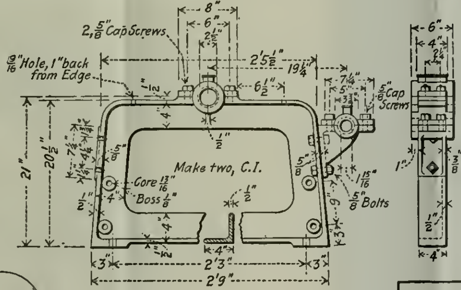
Clutch Lever.



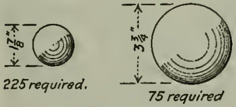
Side Frame.



Trunnion.



End Frame.



Spherical Shot.

STANDARD RATTLER
FOR
TESTING PAVING BRICK
PROPOSED BY
THE NATIONAL PAVING BRICK MANUFACTURERS' ASSOCIATION
December 1, 1910

and shall be inspected at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection showing in what condition the bolts were found

8. *The Frame and Driving Mechanism.*—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates, and shall be fastened thereto by bolts at not less than four points.

It shall be driven by gearing whose ratio of driver to driven is not less than one to four. The counter shaft upon which the driving pinion is mounted shall not be less than $1\frac{15}{16}$ in. in diameter, with bearing not less than 6 in. in length. If a belt drive is used the pulley shall not be less than 18 in. in diameter and $6\frac{1}{2}$ in. in face. A belt at least 6 in. in width properly adjusted, to avoid unnecessary slipping, should be used.

9. *The Abrasive Charge.*—The abrasive charge shall consist of cast-iron spheres of two sizes. When new, the larger spheres shall be 3.75 in. in diameter and shall weigh approximately 7.5 lb. (3.40 kg.) each. Ten spheres of this size shall be used.

These shall be weighed separately after each ten tests, and if the weight of any large sphere falls to 7 lb. (3.175 kg.) it shall be discarded and a new one substituted; provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that so far as possible the large spheres shall compose a graduated series in various stages of wear.

When new, the smaller spheres shall be 1.875 in. in diameter and shall weigh approximately 0.95 lb. (0.43 kg.) each. In general, the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly 300 lb. as possible. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 in. in diameter, drilled in an iron plate $\frac{1}{4}$ in. in thickness, or weigh less than 0.75 lb. (0.34 kg.). Further, the small spheres shall be tested, by passing them over the above plate or by weighing, after every ten tests, and any which pass through or fall below the specified weight, shall be replaced by new spheres; provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon	not under	2.50	per cent
Graphitic carbon	" over	0.25	"
Silicon	" "	1.00	"
Manganese	" "	0.50	"
Phosphorus	" "	0.25	"
Sulfur	" "	0.08	"

For each new batch of spheres used, the chemical analysis shall be furnished by the maker or be obtained by the user, before introducing into the charge, and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

THE OPERATION OF THE TEST.

10. *The Brick Charge.*—The number of bricks per test shall be ten for all bricks of so-called "block-size," whose dimensions fall between 8 and 9 in. in length, 3 and 3¾ in. in breadth, and 3¾ and 4¼ in. in thickness.[1] No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

11. *Speed and Duration of Revolution.*—The rattler shall be rotated at a uniform rate of not less than 29.5 nor more than 30.5 revolutions per minute, and 1800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin not to exceed ten revolutions will be allowed for stopping. Only one start and stop per test is generally acceptable. If, from accidental causes, the rattler is stopped and started more than once during a test, and the loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

12. *The Scales.*—The scales must have a capacity of not less than 300 lb., and must be sensitive to 0.5 oz., and must be tested by a standard test weight at intervals of not less than every ten tests.

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[1] Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.

13. *The Results.*—The loss shall be calculated in percentage of the initial weight of the brick composing the charge. In weighing the rattled brick, any piece weighing less than 1 lb. shall be rejected.

14. *The Records.*—A complete and continuous record shall be kept of the operation of all rattlers working under these specifications. This record shall contain the following data concerning each test made:

1. The name of the person, firm or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street, or contract, which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were received for test.
7. The date on which they were tested.
8. The drying treatment given before testing, if any.
9. The length, breadth and thickness of the bricks.
10. The collective weight of the ten large spherical shot used in making the test at the time of their last standardization.
11. The number and collective weight of the small spherical shot used in making the test, at the time of their last standardization.
12. The total weight of the shot charge, after its last standardization.
13. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them right at the beginning of the test.
14. Certificate of the operator of the number of charges tested since the last standardization of shot charge and last renewals of stave liners.
15. The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test, as shown by the indicator.
16. Certificate of the operator as to number of stops and starts made in each test.
17. The initial collective weight of the ten bricks composing the charge and their collective weight after rattling.
18. The loss calculated in percentage of the initial weight; and the calculation itself.
19. The number of broken bricks and remarks upon the portions which were included in the final weighing.
20. General remarks upon the test and any irregularities occurring in its execution.
21. The date upon which the test was made.
22. The location of the rattler and name of the owner, upon which the test was made.
23. The certificate of the operator that the test was made under the specifications of the American Society for Testing Materials and that the record is a true record.
24. The signature of the operator or person responsible for the test.
25. The serial number of the test.

In the event of more than one copy of the record of any test being required, they may be furnished on separate sheets, and marked duplicates, but the original record shall always be preserved intact and complete.

For the convenience of the public, the accompanying blank form, which provides space for the necessary data, is furnished and its use recommended.

Serial No……………

REPORT OF STANDARD RATTLER TEST OF PAVING BRICK

IDENTIFICATION DATA.

Name of the firm furnishing sample……………………………………

Name of the firm manufacturing sample……………………………………

Street or job which sample represents……………………………………

Brands or marks on the brick……………………………………

Quantity furnished…………………… Drying treatment……………………

Date received…………………… Date tested……………………

Length……………… Breadth……………… Thickness………………

STANDARDIZATION DATA.

Weight of Charge. (After Standardization.)	Condition of Locknuts on Staves.	Condition of Scales.	Number and Position of Fresh Stave Liners.	Repairs. (Note any repairs affecting the condition of the barrel.)
10 Large spheres…….				
Small spheres……..				
Total………….				

Number of charges tested since last inspection ……………………………………

RUNNING DATA.

Time Readings.				Revolution Counter Readings.	Running Notes, Stops, etc.
	Hours.	Minutes.	Seconds.		
Beginning of Test……					
Final Reading……….					

WEIGHTS AND CALCULATIONS.

		Percentage Loss (Note.—The Calculation Must Appear.)
Initial Weight of Ten Bricks……………		
Final Weight of Same…………………		
Loss of Weight………………………		

Number of broken bricks and remarks on same……………………………………

I certify that the foregoing test was made under the specifications of the American Society for Testing Materials, and is a true record.

(Signature of Tester)……………………………………

Date……………………

Location of Laboratory………………………

ACCEPTANCE AND REJECTION OF MATERIAL.

15. *Basis of Acceptance or Rejection.*—Paving bricks shall not be judged for acceptance or rejection by the results of individual tests, but by the average of no less than five tests. Where a lot of bricks fail to meet the required average, it shall be optional with the buyer whether the bricks shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in Section 16.

16. *Range of Fluctuation.*—Some fluctuation in the results of the rattler test, both on account of variations in the bricks and in the machine used in testing, are unavoidable, and a reasonable allowance for such fluctuations should be made, wherever the standard may be fixed.

In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than two per cent, then the portion of the lot represented by that test shall at once be resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than two per cent the required standard, then that portion of the lot shall be rejected.

If in any lot of brick, two or more tests exceed the permissible maximum, then the buyer may at his option reject the entire lot, even though the average of all the tests executed may be within the required limits.

17. *Fixing of Standards.*—The percentage of loss which may be taken as the standard, will not be fixed in these specifications, and shall remain within the province of the contracting parties. For the information of the public, the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications:

	GENERAL AVERAGE LOSS, PER CENT.	MAXIMUM PERMISSIBLE LOSS, PER CENT.
For bricks suitable for heavy traffic..........	22	24
For bricks suitable for medium traffic........	24	26
For bricks suitable for light traffic...........	26	28

Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer, and should be governed by the kind and amount of traffic to be carried, and the quality of paving bricks available.

18. *Culling and Retesting.*—Where, under Sections 15 and 16, a lot or portion of a lot of bricks is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete, the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

19. *Payment of Cost of Testing.*—Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also Section 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it, shall be paid by the seller, whether the material is finally accepted or rejected.

II. VISUAL INSPECTION.

It shall be the right of the buyer to inspect the bricks, subsequent to their delivery at the place of use, and prior to or during laying, to cull out and reject upon the following grounds:

20. All bricks which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where bricks are rejected upon this ground, it shall be the duty of the purchaser to use them so far as practicable in obtaining the necessary half-bricks for breaking courses and making closures, instead of breaking otherwise whole and sound bricks for this purpose.

21. All bricks which are cracked in such a degree as to produce defects such as are defined in Section 20, either from shocks received in shipment and handling, or from defective conditions of manufacture, especially in drying, burning or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

22. All bricks which are so off-size, or so misshapen, bent, twisted or kiln-marked, that they will not form a proper surface as defined by the paving specifications, or align with other

bricks without making joints other than those permitted in the paving specifications.

23. All bricks which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude, as provided in Section 2, and if in either or both tests, the bricks fall beyond the maximum rattler losses permitted under the specifications, then all bricks having the same objectionable appearance may be excluded, and the seller shall pay for the cost of the test. But if under such procedure, the bricks which have been tested as objectionable, shall pass the rattler test, both tests falling within the permitted maximum, then the buyer cannot exclude the class of material represented by this test and he shall pay for the cost of the test.

24. All bricks which differ so markedly in color from the type or average of the shipment, as to make the resultant pavement checkered or disagreeably mottled in appearance. This Section shall not be held to apply to the normal variations in color which may occur in the product of one plant among bricks which will meet the rattler test as referred to in Sections 15, 16, and 17, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture.

STANDARD SPECIFICATIONS
FOR
BUILDING BRICK.

Serial Designation: C 21 – 20.

These specifications are issued under the fixed designation C 21; the final number indicates the year of original adoption as standard, or in the case of revision, the year of the last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED IN AMENDED FORM, 1920.

I. STANDARD SIZE.

Standard Size.

1. The standard size of building brick shall be $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 in.

II. SAMPLING.

Sampling.

2. For the purpose of tests, bricks shall be selected by an experienced person so as to represent the commercial product. All bricks shall be carefully examined and their condition noted before being subjected to any kind of test. For the purpose of the tests ten bricks will be required; they shall be thoroughly dried to constant weight in a suitable oven at a temperature of from 225° F. (107° C.) to 250° F. (121° C.).

III. PHYSICAL TESTS.

Absorption.

3. (*a*) At least five dry bricks shall be weighed and completely submerged in water at a temperature between 60 and 80° F. (15 and 27° C.). The water shall be heated to boiling within one hour, boiled continuously for five hours and then allowed to cool to a temperature between 60 and 80° F. (15 and 27° C.). The bricks shall then be removed, the surface water wiped off with a damp cloth and the brick quickly weighed.

(*b*) The percentage of absorption shall be computed on the dry weight, according to the relation:

$$\text{Percentage of Absorption} = \frac{100\,(B - A)}{A},$$

where A = weight of dry brick and B = weight of saturated brick.

Compression Tests.

4. (*a*) Compression tests shall be made on at least five half bricks, previously dried, each taken from a different brick.

The half brick shall be prepared either by sawing or cutting upon a yielding bed with a sharp mason's chisel, which shall be the full width of the brick. The specimens shall be tested on edge. To secure a uniform bearing in the testing machine the edge surfaces shall be bedded in a thin coat of calcined gypsum (plaster of Paris) spread upon plate glass previously coated with a film of oil. Before applying the calcined gypsum (plaster of Paris), the bearing surface of the brick shall receive a coating of shellac. The brick shall be pressed firmly upon the surface, making the layer as thin as possible, and be permitted to remain undisturbed until set. The depression of recessed or paneled bricks shall be filled with neat Portland-cement mortar, which shall stand at least 24 hours before testing.

(*b*) The machine used for the compression tests shall be equipped with a spherical bearing block kept thoroughly lubricated to insure accurate adjustment, which should be made by hand under a small initial load. During the test the beam of the testing machine shall be kept constantly in a floating position.

(*c*) The breaking load shall be divided by the area in compression and the results reported in pounds per square inch.

Transverse Tests.

5. (*a*) At least five bricks, previously dried, shall be tested, laid flat-wise, with a span of 7 in., and with the load applied at midspan. The knife edges shall be slightly curved in the direction of their length. Steel bearing plates, about $\frac{1}{4}$ in. thick by $1\frac{1}{2}$ in. wide, may be placed between the knife edges and the brick. The use of a wooden base block, slightly rounded transversely across its top, upon which to rest the lower knife edges (see Fig. 1), or the form of lower knife edge shown in Fig. 2, is recommended. If the knife edges shown in Fig. 2 are used, they should rest upon smooth plane blocks of wood at least 2 in. thick.

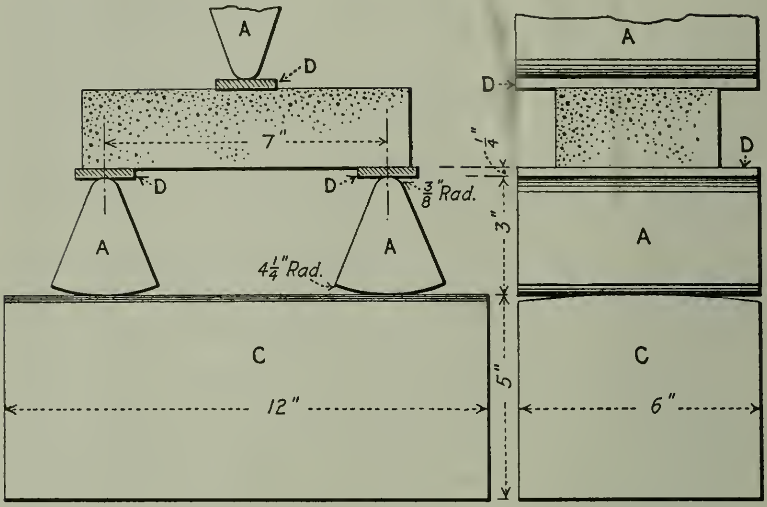
(*b*) The modulus of rupture shall be computed in pounds per square inch by the following formula:

$$R = \frac{3\,Wl}{2\,bd^2},$$

in which l = the distance between supports in inches, b = the breadth and d = depth of the brick in inches, and W = the load in pounds at which the brick failed.

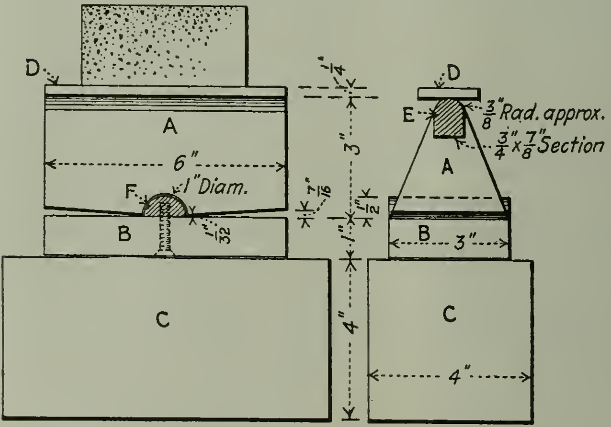
Record of Test Results.

6. In recording the results of the test the type of brick shall be defined, whether stiff mud, soft mud, dry pressed,



A = Cast-Iron Wedges; C = Soft Wood Block; D = Cold-Rolled Steel Plates.

FIG. 1.



A, B = Cast-Iron Wedges; C = Soft Wood Block;
D, E, F = Cold-Rolled Steel.

FIG. 2.

LABORATORY RECORD.

THE ENGINEERING LABORATORY OF..

Brick received from..

Address..

Sampled by.. Date..

Type.. Class (A.S.T.M.)..

Appearance of bricks..

ABSORPTION TEST.

Sample No.	Weight.			Absorption, per cent $\frac{B\text{-}A}{A} \times 100$	Remarks.
	Dry (*A*)	Saturated (*B*)	Difference (*B-A*)		
1					
2					
3					
4					
5					
Sum........	....	....	....		
Average.....	....	....	....		

COMPRESSION TEST.

(HALF BRICKS TESTED ON EDGE.)

Sample No.	Dimensions of half brick.			Load		Compressive Strength, $\left(\frac{L}{a}\right)$ lb. per sq. in.	Remarks.
	Depth (d), in.	Length (l), in.	Area (a) $a=dl$	At First Crack, lb.	At Failure (L), lb.		
1							
2							
3							
4							
5							
Sum.........	....	....	....	....	....		
Average.....	....	....	....	....	....		

TRANSVERSE TEST.

Sample No.	Dimensions.			Load (W), lb.	Modulus of Rupture $R=\frac{3Wl}{2bd^2}$	Remarks.
	Width (b), in.	Depth (d), in.	Span (l), in.			
1						
2						
3						
4						
5						
Sum.........	....	....	....	....		
Average.....	....	....	....	....		

SUMMARY.

Average Absorption, per cent.	Average Compressive Strength, lb. per sq. in.	Average Modulus of Rupture.

Observers:

....

....

In charge of tests.

repressed, sand lime or other types. It is recommended that the data obtained be recorded as indicated on the accompanying "Laboratory Record."

IV. CLASSIFICATION OF BRICKS.

Classification of Bricks.

7. (*a*) According to the results of the physical tests, the bricks shall be classified as vitrified, hard, medium and soft bricks on the basis of the following requirements:

Name of Grade.	Absorption Limits, per cent.		Compressive Strength (on edge), lb. per sq. in.		Modulus of Rupture, lb. per sq. in.	
	Mean of 5 Tests.	Individual Maximum.	Mean of 5 Tests.	Individual Minimum.	Mean of 5 Tests.	Individual Minimum.
Vitrified Brick.	5 or less	6.0	5000 or over	4000	1200 or over	800
Hard Brick....	5 to 12	15.0	3500 or over	2500	600 or over	400
Medium Brick.	12 to 20	24.0	2000 or over	1500	450 or over	300
Soft Brick.....	20 or over	No limit	1000 or over	800	300 or over	200

(*b*) The standing of any set of bricks shall be determined by that one of the three requirements in which it is lowest.

STANDARD SPECIFICATIONS
FOR
CLAY SEWER PIPE.

Serial Designation: C 13 – 20.

These specifications are issued under the fixed designation C 13; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted in Amended Form, 1920.

Material Covered.

1. These specifications cover clay products intended to be used for the conveyance of sewage, industrial wastes and storm water.

Single Class.

2. Sewer pipes furnished under these specifications shall be of a single class to be designated "A.S.T.M. Clay Sewer Pipe."

I. MATERIAL AND MANUFACTURE.

Materials.

3. (*a*) Clay pipes shall be manufactured from surface clay, fire clay or shale, or a combination of these materials.

(*b*) By *surface clay*[1] is meant an unstratified, unconsolidated, plastic glacial or alluvial clay, laid down by the glacial ice sheet, or on the flood plains of rivers, during the present geological epoch.

(*c*) By *fire clay*[1] is meant a stratified clay, usually buff-burning, usually less indurated than shales, with poorly marked cleavage, laid down prior to the present geological epoch.

(*d*) By *shale*[1] is meant a stratified clay, usually red-burning, more or less indurated by heat or pressure, with well-marked cleavage, laid down prior to the present geological epoch.

(*e*) The materials shall possess such physical and chemical properties that when molded into pipes and subjected to a suitable temperature the product will be strong, durable and serviceable, free from objectionable defects, and in compliance with these specifications and tests.

II. CHEMICAL TESTS AND REQUIREMENTS.

Chemical Tests and Requirements.

4. The consumer or purchaser may prescribe in advance special chemical requirements in cases where industrial wastes have marked acid or alkaline character, or are of abnormally high temperatures. He may make use of chemical analysis of

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[1] Definitions of the terms shale, fire clay, and surface clay, and of clays in general as applied to refractories, are now under consideration by Committee E-8 on Nomenclature and Definitions, in cooperation with the several standing committees interested.—Ed.

the pipe material to ascertain whether these special requirements are met. The presence of visible grains or masses of caustic lime, iron pyrites or any other materials which cause slaking or disintegration shall be a cause for rejection.

III. PHYSICAL TESTS.

Physical Tests.

5. The physical tests of pipes shall include: crushing test, hydrostatic pressure test, and absorption test.

Test Specimens.

6. The specimens to be tested shall be selected by the purchaser or his representative at the point or points designated by him when placing the order. The manufacturer or seller shall furnish specimens for test, without separate charge, up to 1 per cent of the number of pipes to be delivered or furnished in each size of pipe. The minimum number of specimens for any delivery less than 200 pieces shall be two specimens in each size of pipe.

Acceptance or Rejection on Result of Tests.

7. Failure of 20 per cent of the specimens to meet the requirements of any of the tests imposed, shall result in rejection of all the pipe in the shipment or delivery, corresponding to the sizes thus failing to comply; except that in the event of 20 per cent of the specimens in any size failing to meet the requirements, the manufacturer or seller may, with the consent of the consumer or purchaser, furnish for test additional specimens from the same shipment without charge. In case more than 80 per cent of the specimens tested, including those first tested, shall show substantial compliance for each of the various tests performed, then the entire shipment or delivery for this size shall be accepted; otherwise it shall be rejected.

Measurement and Observation of Specimens.

8. The specimens of pipes shall be sound, full-size pipe. They shall first be freed from all visible moisture. When dry each specimen shall be weighed, measured and inspected. The results of these observations shall be recorded and preserved as shown in Table I.

Rejection of Defective Specimens.

9. Specimens which, when placed in a vertical position, do not give a metallic ring when struck with a hammer, or are observed to have fire cracks or other defects in form or dimensions in excess of the limits permitted in these specifications, shall be discarded and replaced with additional specimens from the shipment.

(*A*) *Crushing Tests.*

Application of Load.

10. (*a*) Any prime mover or hand power which will apply the load at a uniform rate of about 2000 lb. per minute, or in

TABLE I.—DIMENSIONS, ETC., OF CLAY SEWER PIPE FURNISHED AS TEST SPECIMENS.

Specimen No.	Date.	Job No.	Material.	Manufacturer.	Location of Factory.	Nominal Size, in.	Weight, lb.	Length, ft.	Thickness of Spigot, in.				Thickness of Socket, in.				Internal Diameter, in.						Remarks.
																	Spigot.		Back of Socket.		Socket.		
									Invert.	Crown.	Side.	Side.	Invert.	Crown.	Side.	Side.	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	

increments of not more than 100 lb. at the same rate, may be used in making the test.

(*b*) The pipe shall not be allowed to stand under load longer than is required to apply the load and to observe and record it.

(*c*) The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part.

(*d*) The bearings and the specimen shall be accurately centered so as to secure a symmetrical distribution of the loading on each side of the center of the pipe in every direction.

(*e*) The load shall be applied until the pipe yields by cracks passing through the shell.

Knife or Two-Edge Bearings.

11. (See Fig. 1, Plate III.).—Except as otherwise hereinafter specified, the pipe to be tested shall be supported by a metallic knife bearing 1 in. wide and extended from a point just back of the socket to the spigot end of the pipe. Before the pipe is placed a fillet of plaster of Paris and sand 1 in. wide, and thick enough to compensate for all the inequalities of the pipe barrel, shall be cast on the surface of the knife-edge bearing. The pipe shall be placed upon the fillet while the plaster of Paris is still somewhat plastic. The load shall be applied through an upper knife bearing of the same size and length as the lower bearing. A plaster-of-Paris filet 1 in. wide shall be cast along the length of the crown of the pipe to equalize the lower bearing before the upper one is brought into contact.

Both of the bearings shall be sufficiently rigid to transmit and receive uniform loads throughout their lengths without deflection, and shall be so attached to the machine as to transmit and receive the maximum stresses produced by the tests without lost motion, vibration or sudden shock.

At the option of the consumer or purchaser the crushing test may be applied with sand bearings or with two or three-edge bearings.

The crushing strength shall be calculated by dividing the total load required to break each pipe by the net inside length of the barrel of the pipe, measuring from the bottom of the socket to the end of the spigot; and by then multiplying the quotient by the following factors:

For knife or two-edge bearings........................	$\frac{10}{7}$
" three-edge bearings..............................	$\frac{10}{7}$
" sand bearings....................................	1.00

Three-Edge Bearings.

12. (See Fig. 2, Plate III.).—When three-edge bearings are used, the ends of each specimen of pipe shall be accurately marked in halves of the circumference prior to the test.

The two lower bearings shall consist of two wooden strips with vertical sides, each strip having its interior top corner rounded to a radius of approximately ½ in. They shall be straight, and shall be securely fastened to a rigid block with their interior vertical sides 1 in. apart.

The upper bearing shall be a wooden block, straight and true from end to end.

The test load shall be applied through the upper bearing block in such a way as to leave the bearing free to move in a vertical plane passing midway between the lower bearings.

In testing a pipe which is "out of straight," the lines of the bearings chosen shall be from those which appear to give most favorable conditions for fair bearings.

Sand Bearings.

13. (See Fig. 3, Plate III.).—When sand bearings are used the ends of each specimen of pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean, and shall be such as will pass a No. 4 screen.

The top bearing frame shall not be allowed to come in contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, in such a manner as to permit free motion of the plate in all directions. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.

PLATE III.
1921 A.S.T.M. STANDARDS.

STANDARD SPECIFICATIONS FOR SEWER PIPE.

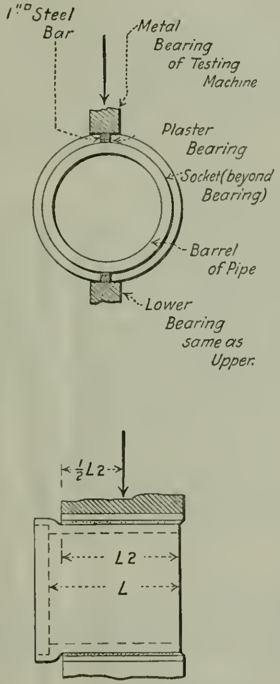

Fig. 1.—Knife or Two-Edge Bearings.

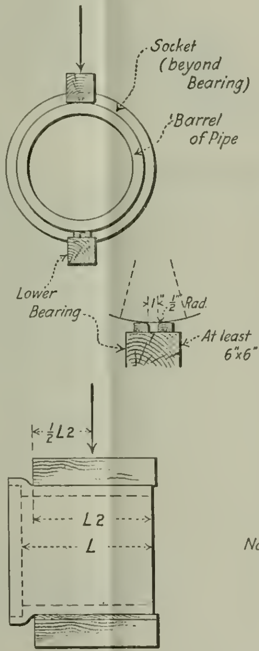

Fig. 2.—Three-Edge Bearings.

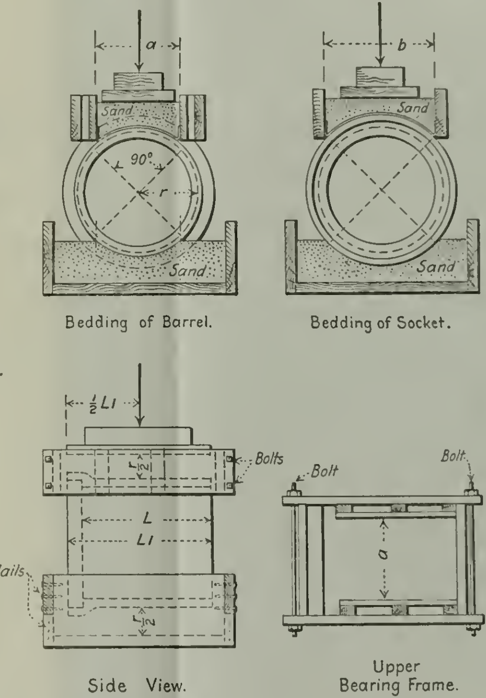

Fig. 3.—Sand Bearings.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

Number of Specimens.

14. The crushing test shall ordinarily be applied to not less than 75 per cent of the specimens received for testing purposes.

Specimens for Absorption Test.

15. Pieces of the crushed pipe may be used as specimens in making the absorption test.

(*B*) *Hydrostatic Test.*

Hydrostatic Test.

16. Sound full-size pipe not exceeding about 25 per cent of the specimens received for test in each size of pipe, shall be tested for leakage under internal hydrostatic pressure.

The ends of the pipe shall be tightly closed by wooden or metallic bulkheads or covers faced with rubber or leather so that no leakage shall occur through the covers at the test pressure. One cover shall be provided with a ¾-in. wrought-iron nipple passing through the cover, and held securely in place and made water-tight by means of locknuts and washers or gaskets. The outer end of the nipple shall be connected with a pump discharge or water service line.

Water pressure, as measured by a standardized gage attached to the delivery pipe close to the specimen, shall be internally applied to the specimen as follows:

5 lb. per sq. in. for 5 minutes.
10 " " " 10 "
15 " " " 15 "

The specimens shall show no leakage under these pressures. Moisture appearing on the surface of the pipe in the form of patches or beads, adhering to the surface, shall not be considered leakage.

(*C*) *Absorption Test.*

Test Specimens.

17. The specimens shall be sound pieces, with all edges broken, and may be from pipes broken in the crushing or other tests. They shall be from 12 to 20 sq. in. in area, and shall be as nearly square as they can be readily prepared. They shall be free from observable cracks, fissures, laminations or shattered edges.

Drying. 18. Preparatory to the absorption test, the specimen shall be first weighed and then dried in a drier or oven at a temperature of not less than 110° C. (230° F.) for not less than three hours. After removal from the drier, the specimen shall be allowed to cool in dry air to a temperature of 20 to 25° C. (68 to 77° F.), and then reweighed.

If the specimen is comparatively dry when taken, and the second weight closely agrees with the first, it shall be considered dry. If the specimen is wet when taken it shall be placed in the drier for a drying treatment of two hours and reweighed. If the third weight checks the second the specimen shall be considered dry. In case of any doubt, the specimen shall be redried for two-hour periods, until check weights are obtained.

Weighing. 19. The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read to the nearest gram. When other than metric weights are used, the same degree of accuracy shall be obtained.

Immersion. 20. The specimen, after final drying, cooling and weighing, shall be placed with other similar specimens in a suitable wire receptacle, packed tightly enough to prevent jostling. covered with distilled water or rainwater, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of 10 to 15° C. (50 to 59° F.).

Reweighing. 21. The specimen shall be allowed to drain for one minute, and, the superficial moisture having been removed by towel or blotting paper, placed upon the balance.

Calculation of Absorption. 22. The test result shall be calculated as percentage of the initial dry weight.

Number of Specimens. 23. One specimen shall be tested of each pipe broken in the crushing test.

Reporting Results. 24. The results shall be reported separately for each individual specimen, together with the mean for all the specimens from the same shipment of pipe.

Identification. 25. Each specimen shall be marked so that it may be identified with the pipe used in the crushing test from which the specimen was taken. The marking shall be applied so that the pigment used shall not cover more than 1 per cent of the total superficial area of the specimen.

IV. PHYSICAL TEST REQUIREMENTS.

Physical Requirements. 26. The test requirements of clay sewer pipe shall be as given in Table II. The individual results of the various tests for each size of pipe and for each shipment class and mill shall be tabulated separately so as to show the percentage which fails to comply with the requirements of each test.

V. A.S.T.M. SIZES AND DIMENSIONS.

Sizes and Dimensions.

27. Pipes shall be furnished of the sizes, internal diameter, and with the dimensions given in Tables III and IV. Where several lengths are mentioned in the table the consumer or purchaser shall indicate, at the time of purchase, which lengths shall be furnished; and unless so indicated, the manufacturer shall furnish such lengths as he may elect.

TABLE II.—PHYSICAL TEST REQUIREMENTS OF CLAY SEWER PIPE.

Internal Diameter, in.	Minimum Crushing Strength,[1] lb. per lin. ft.	Maximum Absorption, per cent.
4	1430	8
6	1430	8
8	1430	8
10	1570	8
12	1710	8
15	1960	8
18	2200	8
21	2590	8
24	3070	8
27	3370	8
30	3690	8
33	3930	8
36	4400	8
39	4710	8
42	5030	8

[1] See end of Section 11.

Permissible Variations.

28. The permissible variation from the dimensions given in Table III shall not exceed those stated in Table IV. Where the thickness of barrel is increased beyond that given in Table IV in order to meet the specified requirements of strength, the diameter at inside of socket shall be increased by double the increase in thickness of barrel. Pipes intended to be straight shall not have variation in alignment of more than ⅛ in. per foot of length.

VI. WORKMANSHIP AND FINISH.

Absence of Defects. 29. Pipes shall be substantially free from fractures, large or deep cracks and blisters, laminations and surface roughness.

Scored Ends. 30. The inner surface of the socket and the outer surface of the spigot end shall be scored by triangular shaped or semi-circular shaped rings about $\frac{1}{8}$ in. deep.

The number of scorings shall be as follows:

For pipes 4 to 6 in. in internal diameter, inclusive ....none
" " 8 " 10 " " " " 2
" " 12 " 21 " " " " 3
" " 24 " 30 " " " " 4
" " 33 " 42 " " " " 5

TABLE III.—DIMENSIONS OF CLAY SEWER PIPE.

Internal Diameter (D), in.	Laying Length (L), ft.	Inside Diameter at Mouth of Socket (D_s), in.[1]	Depth of Socket (L_s), in.	Minimum Taper of Socket (H).	Thickness of Barrel (T), in.	Thickness of Socket (T_s).
4	2	6	$1\frac{1}{2}$	1 : 20	$\frac{9}{16}$	The thickness of the socket $\frac{1}{4}$ in. from its outer end shall not be less than three-fourths of the thickness of the barrel of the pipe.
6	2	$8\frac{1}{4}$	2	1 : 20	$\frac{5}{8}$	
8	2, $2\frac{1}{2}$, 3	$10\frac{3}{4}$	$2\frac{1}{4}$	1 : 20	$\frac{3}{4}$	
10	2, $2\frac{1}{2}$, 3	13	$2\frac{1}{2}$	1 : 20	$\frac{7}{8}$	
12	2, $2\frac{1}{2}$, 3	$15\frac{1}{4}$	$2\frac{1}{2}$	1 : 20	1	
15	2, $2\frac{1}{2}$, 3	$18\frac{3}{4}$	$2\frac{1}{2}$	1 : 20	$1\frac{1}{4}$	
18	2, $2\frac{1}{2}$, 3	$22\frac{1}{4}$	3	1 : 20	$1\frac{1}{2}$	
21	2, $2\frac{1}{2}$, 3	26	3	1 : 20	$1\frac{3}{4}$	
24	2, $2\frac{1}{2}$, 3	$29\frac{1}{2}$	3	1 : 20	2	
27	3	$33\frac{1}{4}$	$3\frac{1}{2}$	1 : 20	$2\frac{1}{4}$	
30	3	37	$3\frac{1}{2}$	1 : 20	$2\frac{1}{2}$	
33	3	$40\frac{1}{4}$	4	1 : 20	$2\frac{5}{8}$	
36	3	44	4	1 : 20	$2\frac{3}{4}$	
39	3	$47\frac{1}{4}$	4	1 : 20	$2\frac{7}{8}$	
42	3	51	4	1 : 20	3	

[1] When pipes are furnished having an increase in thickness over that given in last column, the diameter of socket shall be increased by an amount equal to twice the increase of thickness of barrel.

Salt Glaze. 31. The glaze shall consist of a continuous layer of bright or semi-bright glass substantially free from coarse blisters and pimples. If present none of these shall project more than $\frac{1}{8}$ in. above the surrounding surface. Not more than 10 per cent of the inner surface of any pipe barrel shall be bare of glaze except the socket, where it may be entirely absent. Glazing will not be required on the outer surface of the barrel at the spigot end for a distance from the end equal to two-thirds the specified depth of socket for the corresponding size of pipe. Where glazing is required there shall be absence of any well-defined net work of crazing lines or hair cracks. All glazing shall be equal to that produced by the best salt-glazing process.

Finish of Ends

32. The ends of the pipes shall be square with their longitudinal axis, except as provided in Table IV.

Specials.

33. (*a*) Special shapes shall have a plain spigot end and a socket end corresponding in all respects with the dimensions specified for pipes of the corresponding internal diameter. Branch pipes shall be furnished to lay the same lengths as straight pipe. All specials shall conform in finish to the specifications for pipes given in Sections 29, 30, 31 and 32.

TABLE IV.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF CLAY SEWER PIPE.

Normal Size, in.	Limits of Permissible Variation in:					
	Length, in. per ft. (–)	Lengths of Two Opposite Sides, in.	Internal Diameter, in.		Depth of Socket, in. (–)	Thickness of Barrel, in. (–)
			Spigot (±)	Socket (±)		
4	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$
6	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{16}$
8	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{16}$
10	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{16}$
12	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{16}$
15	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{32}$
18	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{32}$
21	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$
24	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{1}{8}$
27	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{1}{4}$	$\frac{1}{8}$
30	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{1}{4}$	$\frac{1}{8}$
33	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
36	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
39	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
42	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{3}{16}$

NOTE.—The minus sign (–) alone indicates that the plus variation is not limited; the plus and minus sign (±) indicates variation in both excess and deficiency in dimension.

(*b*) Slants shall have their spigot ends cut at an angle of approximately 45 deg. with the longitudinal axis.

(*c*) Curves shall be at angles of 90, 45, 22½ deg., as required. They shall conform substantially to the curvature specified.

(*d*) Branches shall be furnished with the connection or connections of the size or sizes specified, securely and completely fastened by fusion in the process of vitrification to the barrel of the pipe. T-branches and double T-branches shall have the axis perpendicular to the longitudinal axis of the pipe. Y-branches, double Y-branches, and V-branches shall have their axes approximately 45 deg. from the longitudinal axis of the pipe measured from the socket end. All branches shall terminate in sockets and the barrel of the branch shall be of sufficient length to permit making a proper joint when the connecting pipe is inserted in the branch socket.

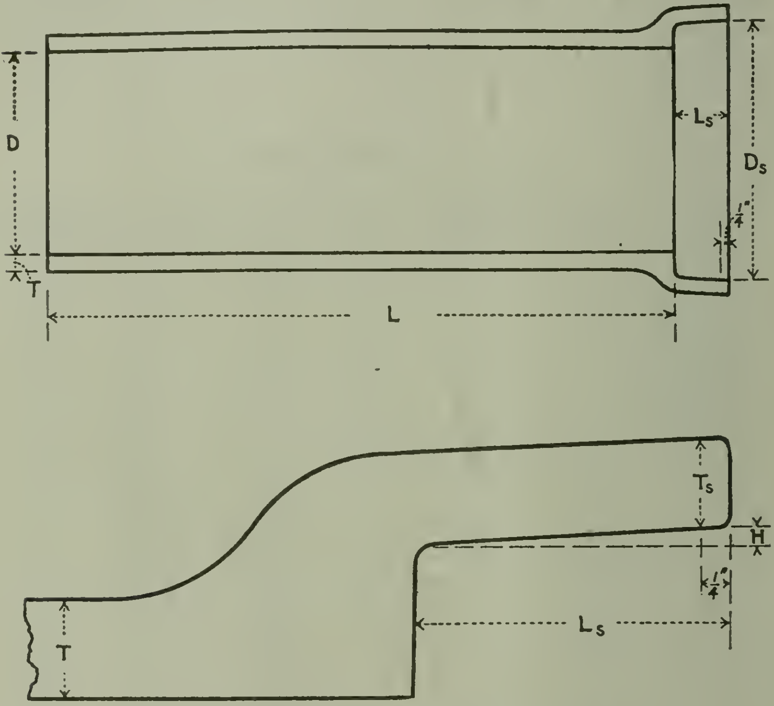

FIG. 4.—Application of Dimensions given in Table III.

(*e*) Channel or split pipes, curves and branches shall be accurate half sections of the corresponding size of straight pipe and specials.

VII. MARKINGS.

Markings. 34. Pipes shall bear the initials or name of the person, company or corporation by whom they are manufactured, and the location of the mill. The markings shall be indented on the exterior of the barrel near the socket and shall be plainly legible for purpose of identification.

VIII. INSPECTION.

Inspection.

35. All pipes shall be subject to inspection at the factory, trench or other point of delivery by a competent inspector employed by the consumer or purchaser. The purposes of the inspection shall be to cull and reject pipes which, independent of the physical tests herein specified, fail to comply with the requirements of these specifications.

Rejection.

36. Pipes shall be subject to rejection on account of the following:

(*a*) Variations in any dimension exceeding the permissible variations given in Table IV.

(*b*) Fracture or cracks passing through the shell or socket, except that a single crack at either end of a pipe not exceeding 2 in. in length or a single fracture in the socket not exceeding 3 in. in width nor 2 in. in length will not be deemed cause for rejection unless these defects exist in more than 5 per cent of the entire shipment or delivery.

(*c*) Blisters where the glazing is broken or which exceed 3 in. in diameter, or which project more than $\frac{1}{8}$ in. above the surface.

(*d*) Laminations which indicate extended voids in the pipe material.

(*e*) Fire cracks or hair cracks sufficient to impair the strength, durability or serviceability of the pipe.

(*f*) Variation of more than $\frac{1}{8}$ in. per linear foot in alignment of a pipe intended to be straight.

(*g*) Glaze which does not fully cover and protect all parts of the shell and ends except those exempted in Section 31; also glaze which is not equal to best salt glaze.

(*h*) Failure to give a clear ringing sound when placed on end and dry-tapped with a light hammer.

(*i*) Insecure attachment of branches on spurs.

Marking of Rejected Specimens.

37. All rejected pipes shall be plainly marked by the inspector and shall be replaced by the manufacturer or seller with pipes which meet the requirements of these specifications, without additional cost to the consumer or purchaser.

STANDARD SPECIFICATIONS

FOR

CEMENT-CONCRETE SEWER PIPE.

Serial Designation: C 14 – 20.

These specifications are issued under the fixed designation C 14; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted in Amended Form, 1920.

Material Covered. 1. These specifications cover cement-concrete products intended to be used for the conveyance of sewage, industrial wastes and storm water.

Single Class. 2. Pipes furnished under these specifications shall be of a single class to be designated "A.S.T.M. Cement-Concrete Sewer Pipe."

I. MATERIAL AND MANUFACTURE.

Materials. 3. (*a*) Cement-concrete pipes shall be manufactured from Portland-cement concrete.

(*b*) *Concrete.*—By concrete is meant a suitable mixture of Portland cement, mineral aggregates and water, hardened by hydraulic chemical action.

(*c*) *Cement.*—Portland cement shall meet the requirements of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials.

(*d*) The materials shall possess such physical and chemical properties that when molded into pipes and properly cured the product will be strong, durable and serviceable, free from objectionable defects, and in compliance with these specifications and tests.

II CHEMICAL TESTS AND REQUIREMENTS.

Chemical Tests and Requirements. 4. The consumer or purchaser may prescribe in advance special chemical requirements in cases where sewage, industrial wastes or ground waters have marked acid or alkaline character, or are of abnormally high temperatures. He may make use of chemical analysis of the pipe materials to ascertain whether these special requirements are met. The presence of deleterious materials causing slaking or disintegration shall be cause for rejection.

III. PHYSICAL TESTS.

Physical Tests.

5. The physical tests of pipes shall include: crushing test, hydrostatic pressure test and absorption test.

Test Specimens.

6. The specimens to be tested shall be selected by the purchaser or his representative at the point or points designated by him when placing the order. The manufacturer or seller shall furnish specimens for test, without separate charge, up to 1 per cent of the number of pipes to be delivered or furnished in each size of pipe. The minimum number of specimens for any delivery less than 200 pieces shall be two specimens of each size of pipe.

Acceptance or Rejection on Result of Tests.

7. Failure of 20 per cent of the specimens to meet the requirements of any of the tests imposed, shall result in rejection of all the pipe in the shipment or delivery, corresponding to the sizes thus failing to comply; except that in the event of 20 per cent of the specimens in any size failing to meet the requirements, the manufacturer or seller may, with the consent of the consumer or purchaser, furnish for test additional specimens from the same shipment without charge. In case more than 80 per cent of the specimens tested, including those first tested, shall show substantial compliance for each of the various tests performed, then the entire shipment or delivery for this size shall be accepted; otherwise it shall be rejected.

Measurement and Observation of Specimens.

8. The specimens of pipes shall be sound, full-size pipe. They shall first be freed from all visible moisture. When dry each specimen shall be weighed, measured and inspected. The results of these observations shall be recorded and preserved as shown in Table I.

Rejection of Defective Specimens.

9. Specimens which, when placed in a vertical position, do not give a metallic ring when struck with a hammer, or are observed to have cracks or other defects in form or dimensions in excess of the limits permitted in these specifications, shall be discarded and replaced with additional specimens from the shipment.

(*A*) *Crushing Test.*

Application of Load.

10. (*a*) Any prime mover or hand power which will apply the load at a uniform rate of about 2000 lb. per minute, or in incre-

TABLE I.—DIMENSIONS, ETC., OF CEMENT-CONCRETE SEWER PIPE FURNISHED AS TEST SPECIMENS.

Specimen No.	Date.	Job No.	Material.	Manufacturer.	Location of Factory.	Nominal Size, in.	Weight, lb.	Length, ft.	Thickness of Spigot, in.				Thickness of Socket, in.				Internal Diameter, in.						Remarks.
																	Spigot.		Back of Socket.		Socket.		
									Invert.	Crown.	Side.	Side.	Invert.	Crown.	Side.	Side.	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	

ments of not more than 100 lb. at the same rate, may be used in making the test.

(*b*) The pipe shall not be allowed to stand under load longer than is required to apply the load and to observe and record it.

(*c*) The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part.

(*d*) The bearings and the specimen shall be accurately centered so as to secure a symmetrical distribution of the loading on each side of the center of the pipe in every direction.

(*e*) The load shall be applied until the pipe yields by cracks passing through the shell.

Knife or Two-Edge Bearings.

11. (See Fig. 1, Plate III.)[1]—Except as otherwise hereinafter specified, the pipe to be tested shall be supported by a metallic knife bearing 1 in. wide and extended from a point just back of the socket to the spigot end of the pipe. Before the pipe is placed a fillet of plaster of Paris and sand 1 in. wide, and thick enough to compensate for all the inequalities of the pipe barrel, shall be cast on the surface of the knife bearing. The pipe shall be placed upon the fillet while the plaster of Paris is still somewhat plastic. The load shall be applied through an upper knife bearing of the same size and length as the lower bearing. A plaster-of-Paris fillet 1 in. wide shall be cast along the length of the crown of the pipe to equalize the lower bearing before the upper one is brought into contact.

Both of the bearings shall be sufficiently rigid to transmit and receive uniform loads throughout their lengths without deflection, and shall be so attached to the machine as to transmit and receive the maximum stresses produced by the tests without lost motion, vibration or sudden shock.

At the option of the consumer or purchaser the crushing test may be applied with sand bearings or with two or three-edge bearings.

The crushing strength shall be calculated by dividing the total load required to break each pipe by the net inside length of the barrel of the pipe, measuring from the bottom of the socket to the end of the spigot; and by then multiplying the quotient by the following factors:

For knife or two-edge bearings........................	$\frac{10}{7}$
" three-edge bearings	$\frac{10}{7}$
" sand bearings.................................	1.00

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[1] See p. 588.

Three-Edge Bearings.

12. (See Fig. 2, Plate III.)[1].—When three-edge bearings are used, the ends of each specimen of pipe shall be accurately marked in halves of the circumference prior to the test.

The two lower bearings shall consist of two wooden strips with vertical sides, each strip having its interior top corner rounded to a radius of approximately ½ in. They shall be straight, and shall be securely fastened to a rigid block with their interior vertical sides 1 in. apart.

The upper bearing shall be a wooden block, straight and true from end to end.

The test load shall be applied through the upper bearing block in such a way as to leave the bearing free to move in a vertical plane passing midway between the lower bearings.

In testing a pipe which is "out of sight," the lines of the bearings chosen shall be from those which appear to give most favorable conditions for fair bearings.

Sand Bearings

13. (See Fig. 3, Plate III.)[1].—When sand bearings are used, the ends of each specimen of pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean, and shall be such as will pass a No. 4 screen.

The top bearing frame shall not be allowed to come in contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, in such a manner as to permit free motion of the plate in all directions. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.

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[1] See p. 588.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

Number of Specimens.

14. The crushing test shall ordinarily be applied to not less than 75 per cent of the specimens received for testing purposes.

Specimens for Absorption Test.

15. Pieces of the crushed pipe may be used as specimens in making the absorption test.

(*B*) *Hydrostatic Test.*

Hydrostatic Test.

16. Sound full-size pipe not exceeding about 25 per cent of the specimens received for test in each size of pipe, shall be tested for leakage under internal hydrostatic pressure.

The ends of the pipe shall be tightly closed by wooden or metallic bulkheads or covers faced with rubber or leather so that no leakage shall occur through the covers at the test pressure. One cover shall be provided with a ¾-in. wrought-iron nipple passing through the cover, and held securely in place and made water-tight by means of locknuts and washers or gaskets. The outer end of the nipple shall be connected with a pump discharge or water service line.

Water pressures, as measured by a standardized gage attached to the delivery pipe close to the specimen, shall be nternally applied to the specimen as follows:

5 lb. per sq. in. for 5 minutes
10 " " for 10 "
15 " " for 15 "

The specimens shall show no leakage under these pressures. Moisture appearing on the surface of the pipe in the form of patches or beads, adhering to the surface, shall not be considered leakage.

(*C*) *Absorption Test.*

Test Specimens.

17. The specimens shall be sound pieces with all edges broken, and may be from pipes broken in the crushing or other tests. They shall be from 12 to 20 sq. in. in area, and shall be as nearly square as they can be readily prepared. They shall be free from observable cracks, fissures, laminations or shattered edges.

Drying. 18. Preparatory to the absorption test, the specimen shall be first weighed and then dried in a drier or oven at a temperature of not less than 110° C. (230° F.) for not less than three hours. After removal from the drier, the specimen shall be allowed to cool in dry air to a temperature of 20 to 25° C. (68 to 77° F.), and then reweighed.

If the specimen is comparatively dry when taken, and the second weight closely agrees with the first, it shall be considered dry. If the specimen is wet when taken it shall be placed in the drier for a drying treatment of two hours and reweighed. If the third weight checks the second the specimen shall be considered dry. In case of any doubt, the specimen shall be redried for two-hour periods, until check weights are obtained

Weighing. 19. The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read to the nearest gram. When other than metric weights are used, the same degree of accuracy shall be obtained.

Immersion. 20. The specimen, after final drying, cooling and weighing shall be placed with other similar specimens in a suitable wire receptacle, packed tightly enough to prevent jostling, covered with distilled water or rainwater, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of 10 to 15° C. (50 to 59° F.).

Reweighing. 21. The specimen shall be allowed to drain for one minute, and, the superficial moisture having been removed by towel or blotting paper, placed upon the balance.

Calculation of Absorption. 22. The test result shall be calculated as percentage of the initial dry weight.

Number of Specimens. 23. One specimen shall be tested of each pipe broken in the crushing test.

Reporting Results. 24. The results shall be reported separately for each individual specimen together with the mean for all the specimens from the same shipment of pipe.

Identification. 25. Each specimen shall be marked so that it may be identified with the pipe used in the crushing test from which the specimen was taken. The marking shall be applied so that the pigment used shall not cover more than 1 per cent of the total superficial area of the specimen.

IV. PHYSICAL TEST REQUIREMENTS.

Physical Test Requirements. 26. The test requirements of cement-concrete pipe shall be as given in Table II. The individual results of the various tests for each size of pipe and for each shipment class and mill shall be tabulated separately so as to show the percentage which fails to comply with the requirements of each test.

V. A.S.T.M. SIZES AND DIMENSIONS.

Sizes and Dimensions.

27. Pipes shall be furnished of the sizes, internal diameter, and with the dimensions given in Tables III and IV. Where several lengths are mentioned in the table the consumer or purchaser shall indicate, at the time of purchase, which lengths shall be furnished; and unless so indicated, the manufacturer shall furnish such lengths as he may elect.

TABLE II.—PHYSICAL TEST REQUIREMENTS OF CEMENT-CONCRETE SEWER PIPE.

Internal Diamter, in.	Minimum Crushing Strength, lb. per lin. ft.	Maximum Absorption, per cent.
4	1430	8
6	1430	8
8	1430	8
10	1570	8
12	1710	8
15	1960	8
18	2200	8
21	2590	8
24	3070	8
27	3370	8
30	3690	8
33	3930	8
36	4400	8
39	4710	8
42	5030	8

Permissible Variations.

28. The permissible variation from the dimensions given in Table III shall not exceed those stated in Table IV. Where the thickness of barrel is increased beyond that given in Table III in order to meet the specified requirements of strength, the diameter at inside of socket shall be increased by double the increase in thickness of barrel. Pipes intended to be straight shall not have variation in alignment of more than $\frac{1}{8}$ in. per foot of length.

VI. WORKMANSHIP AND FINISH.

Absence of Defects. 29. Pipes shall be substantially free from fractures, large or deep cracks and blisters, laminations and surface roughness.

Finish of Ends. 30. The ends of the pipes shall be square with their longitudinal axis.

Specials. 31. (*a*) Special shapes shall have a plain spigot end and a socket end corresponding in all respects with the dimensions specified for pipes of the corresponding internal diameter. Branches shall be furnished to lay the same lengths as straight pipe. All specials shall conform in finish to the specifications for pipes given in Sections 29 and 30.

TABLE III.—DIMENSIONS OF CEMENT-CONCRETE SEWER PIPE.

Internal Diameter (D), in.	Laying Length (L), ft.	Inside Diameter at Mouth of Socket (D_S), in.[1]	Depth of Socket (L_S), in.	Minimum Taper of Socket (H)	Thickness of Barrel (T), in.	Thickness of Socket (T_S).
4	2, 2½	6	1½	1 : 20	9/16	The thickness of the socket ½ in. from its outer end shall be not less than three-fourths of the thickness of the barrel of the pipe.
6	2, 2½	8¼	2	1 : 20	⅝	
8	2, 2½, 3	10¾	2¼	1 : 20	¾	
10	2, 2½, 3	13	2½	1 : 20	⅞	
12	2, 2½, 3	15¼	2½	1 : 20	1	
15	2, 2½, 3	18¾	2½	1 : 20	1¼	
18	2, 2½, 3	22¼	2¾	1 : 20	1½	
21	2, 2½, 3	26	2¾	1 : 20	1¾	
24	2, 2½, 3	29½	3	1 : 20	2⅛	
27	3	33¼	3¼	1 : 20	2¼	
30	3	37	3½	1 : 20	2½	
33	3	40¼	4	1 : 20	2¾	
36	3	44	4	1 : 20	3	
39	3	47¼	4	1 : 20	3¼	
42	3	51	4	1 : 20	3½	

[1] When pipes are furnished having an increase in thickness over that given in last column, then the diameter of socket shall be increased by an amount equal to twice the increase of thickness of barrel.

(*b*) Slants shall have their spigot ends cut at an angle of approximately 45 deg. with the longitudinal axis.

(*c*) Curves shall be at angles of 90, 45, 22½ deg., as required. They shall conform substantially to the curvature specified.

(*d*) Branches shall be furnished with the connection or connections of the size or sizes specified, securely and completely fastened in the process of manufacture to the barrel of the pipe. T-branches and double T-branches shall have the axis perpendicular to the longitudinal axis of the pipe. Y-branches, double

Y-branches, and V-branches shall have their axes approximately 45 deg. from the longitudinal axis of the pipe measured from the socket end. All branches shall terminate in sockets and the barrel of the branch shall be of sufficient length to permit making a proper joint when the connecting pipe is inserted in the branch socket.

(*e*) Channel or split pipe, curves and branches shall be accurate half sections of the corresponding size of pipe or other specials.

TABLE IV.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF CEMENT-CONCRETE SEWER PIPE.

Normal Size, in.	Limits of Permissible Variation in:				
	Length, in. per ft. (−)	Internal Diameter, in.		Depth of Socket, in. (−)	Thickness of Barrel, in. (−)
		Spigot (±)	Socket (±)		
4	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$
6	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{16}$
8	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{16}$
10	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{16}$
12	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{16}$
15	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{32}$
18	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{32}$
21	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{8}$
24	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{8}$
27	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{8}$
30	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
33	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$
36	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$
39	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$
42	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$

NOTE.—The minus sign (−) alone indicates that the plus variation is not limited; the plus and minus sign (±) indicates variation in both excess and deficiency in dimension.

VII. MARKINGS.

32. Pipes shall bear the initials or name of the person, company or corporation by whom they are manufactured, and the location of the mill. The markings shall be indented or stenciled on the exterior or interior of the barrel near the socket and shall be plainly legible for purpose of identification. **Markings.**

VIII. INSPECTION.

33. All pipes shall be subject to inspection at the factory, trench or other point of delivery by a competent inspector **Inspection.**

employed by the consumer or purchaser. The purposes of the inspection shall be to cull and reject pipes which, independent of the physical tests herein specified, fail to meet the requirements of these specifications.

Rejection

34. Pipes shall be subject to rejection on account of the following:

(*a*) Variations in any dimension exceeding the permissible variations given in Table IV.

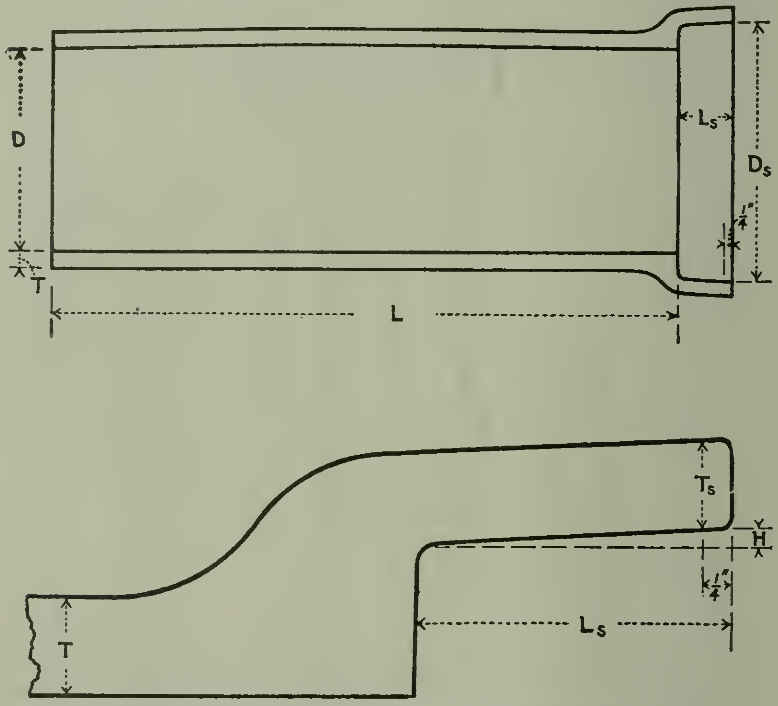

FIG. 4.—Application of Dimensions given in Table III.

(*b*) Fracture or cracks passing through the shell or socket, except that a single crack at either end of a pipe not exceeding 2 in. in length or a single fracture in the socket not exceeding 3 in. in width nor 2 in. in length will not be deemed cause for rejection unless these defects exist in more than 5 per cent of the entire shipment or delivery.

(*c*) Blisters where the surface is broken or which project more than $\frac{1}{8}$ in. above the surface.

(*d*) Defects which indicate imperfect mixing and molding.

(*e*) Cracks sufficient to impair the strength, durability or serviceability of the pipe.

(*f*) Variation of more than $\frac{1}{8}$ in. per linear foot in alignment of a pipe intended to be straight.

(*g*) Failure to give a clear ringing sound when placed on end and dry-tapped with a light hammer.

(*h*) Insecure attachment of branches on spurs.

Marking of Rejected Specimens.

35. All rejected pipes shall be plainly marked by the inspector and shall be replaced by the manufacturer or seller with pipes which meet the requirements of these specifications, without additional cost to the consumer or purchaser.

STANDARD SPECIFICATIONS
FOR
GYPSUM PLASTERS.

Serial Designation: C 28 – 21

These specifications are issued under the fixed designation C 28; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1920; Adopted in Amended Form, 1921.

Testing. 1. The chemical and physical properties of gypsum plasters shall be determined in accordance with the Tentative Methods of Testing Gypsum and Gypsum Products (Serial Designation: C 26 – 21 T) of the American Society for Testing Materials.[1]

I. GYPSUM READY-SANDED PLASTER.

Definition. 2. Gypsum ready-sanded plaster is a plastering material in which the predominating cementitious material is calcined gypsum, and which is mixed at the mill with all the constituent parts, including sand, in their proper proportion. It requires only the addition of water to make it ready for use.

Composition. 3. The following shall govern the composition of gypsum ready-sanded plaster for the desired coats:

(*a*) *Scratch or First Coat.*—Gypsum ready-sanded plaster used for scratch or first coat shall contain not more than two-thirds by weight of sand. The remainder shall contain not less than 75 per cent of its weight of calcined gypsum. The other 25 per cent of this remainder may consist of materials to control the working quality, setting time, and the fibering.[2]

(*b*) *Browning or Second Coat.*—Gypsum ready-sanded plaster used for browning or second coat shall contain not more than 75 per cent by weight of sand. The remainder shall contain not less than 75 per cent by weight of calcined gypsum. The other 25 per cent of this remainder may consist of materials to control the working quality, setting time, and the fibering.[2]

Time of Setting. 4. The time of set of gypsum ready-sanded plaster shall be as follows:

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. 21 (1921).

[2] The U. S. Bureau of Standards is investigating the effect of Portland cement mixed in gypsum plasters. A report on these investigations is forthcoming.

(*a*) *Scratch or First Coat.*—This plaster shall set in not less than 1½ nor more than 7 hours.

(*b*) *Browning or Second Coat.*—This plaster shall set in not less than 2 nor more than 6 hours.

Tensile Strength. 5. The tensile strength of gypsum ready-sanded plaster shall be as follows:

(*a*) *Scratch or First Coat.*—This plaster shall have a tensile strength of not less than 75 lb. per sq. in. (5¼ kg. per sq. cm.).

(*b*) *Browning or Second Coat.*—This plaster shall have a tensile strength of not less than 50 lb. per sq. in. (3½ kg. per sq. cm.).

II. GYPSUM NEAT PLASTER.

Definition 6. Gypsum neat plaster is a plastering material in which not less than 85 per cent of the cementitious material is calcined gypsum mixed at the mill with other materials.

Composition. 7. Gypsum neat plaster shall contain not less than 85 per cent by weight of calcined gypsum. The remainder may consist of materials to control the working quality, setting time, and the fibering[1]

Time of Setting. 8. Gypsum neat plaster shall set in not less than 1½ hours.

Tensile Strength. 9. Gypsum neat plaster shall have a tensile strength of not less than 150 lb. per sq. in. (10½ kg. per sq. cm.).

III. GYPSUM WOOD-FIBERED PLASTER.

Definition. 10. Gypsum wood-fibered plaster is a gypsum plaster in which wood fiber is used as an aggregate.

Composition. 11. Gypsum wood-fibered plaster shall contain not less than 80 per cent by weight of calcined gypsum, and not less than 1 per cent by weight of wood fiber made from a non-staining wood. The remainder may consist of materials to control the working quality and setting time.[1]

Time of Setting. 12. Gypsum wood-fibered plaster shall set in not less than 1½ nor more than 8 hours.

Tensile Strength. 13. Gypsum wood-fibered plaster shall have a tensile strength of not less than 125 lb. per sq. in. (8¾ kg. per sq. cm.).

IV. CALCINED GYPSUM FOR FINISHING COAT.

Definition. 14. Calcined gypsum for finishing coat may, or may not, contain retarder. It may be classified in two grades, viz: "White" and "Gray."

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[1] The U. S. Bureau of Standards is investigating the effect of Portland cement mixed in gypsum plasters. A report on these investigations is forthcoming.

Fineness. 15. Calcined gypsum for finishing coat shall all pass a 14-mesh sieve, and not less than 60 per cent of it shall pass through a 100-mesh sieve.

Time of Setting. 16. Calcined gypsum for finishing coat when not retarded shall set in not less than 20 minutes nor more than 40 minutes, and when retarded shall set in not less than 40 minutes nor more than 6 hours.

Tensile Strength 17. Calcined gypsum for finishing coat shall have a tensile strength of not less than 200 lb. per sq. in. (14 kg. per sq. cm.).

V. SAMPLING.

Sampling. 18. At least 3 per cent of the packages shall be sampled, and shall be so selected as to be representative of the contents of the shipment. Samples shall be taken from both the surface and the center of the packages. The material so obtained shall be thoroughly mixed and reduced by quartering to provide not less than a 15-lb. (7.5 kg.) sample for the laboratory.

Laboratory Samples. 19. All laboratory samples shall immediately be placed in an air-tight container and shipped to the laboratory for test.

VI. PACKING AND MARKING.

Packing and Marking. 20. (*a*) Gypsum plasters shall be dry and free from lumps, and may be shipped either in packages or in bulk.

(*b*) When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of Manufacturer.
Brand.
Description.
Net weight of package.

(*c*) When shipped in bulk, a card containing the required information shall be conspicuously placed in the carrier.

VII. INSPECTION AND REJECTION.

Inspection. 21. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carrier being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection. 22. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these specifications, and shall be reported within ten working days from the receipt of the shipment by the consignee.

Rehearing 23. Claim for rehearing shall be valid only if made within twenty working days from receipt of notice of specific cause for rejection.

NOTE.

The water used for mixing gypsum plasters shall be fresh, pure and clean. Trouble may occur from the presence of any excessive amount of mineral or organic substances in the water.

EDITORIAL NOTE.

Specifications for color of calcined gypsum for finishing coat will be formulated when sufficient information is available to warrant such procedure.

STANDARD SPECIFICATIONS
FOR
FIRE TESTS OF MATERIALS AND CONSTRUCTION.

Serial Designation: C 19 – 18.

These specifications are issued under the fixed designation C 19; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted, 1918.

**These specifications were approved March 1, 1919,
as Tentative American Standard by the
American Engineering Standards Committee.**

I. CONTROL OF FIRE TESTS.

Time-Temperature Curve.

1. The conduct of fire tests of materials and construction shall be controlled by the standard time-temperature control curve shown in Fig. 1. The points on the curve which determine its character are,

1000°	F.	at	5	minutes
1300	"	"	10	"
1550	"	"	30	"
1700	"	"	1	hour
1850	"	"	2	"
2000	"	"	4	"
2300	"	"	8	"

Determination of Temperatures.

2. (*a*) The temperature fixed by the curve shall be deemed to be the average true temperature of the furnace gases as obtained from the readings of several thermo-couples (not less than three) symmetrically disposed and distributed in such a manner as to show the temperatures of the gases near all parts of the sample.

(*b*) The temperatures shall be read at intervals not exceeding 5 minutes during the first hour, and thereafter the intervals may be increased to not more than 15 minutes.

II. CLASSIFICATION AS DETERMINED BY TEST.

Classification.

3. (*a*) Fire-resistive materials and construction shall be classified in accordance with the degree of protection they

afford when measured by a fire test conducted in conformity with the standard time-temperature control curve as,

4-hour Protection
2 " "
1 " "
½ " "
¼ " "

(*b*) Other classes may be interpolated or added as needed.

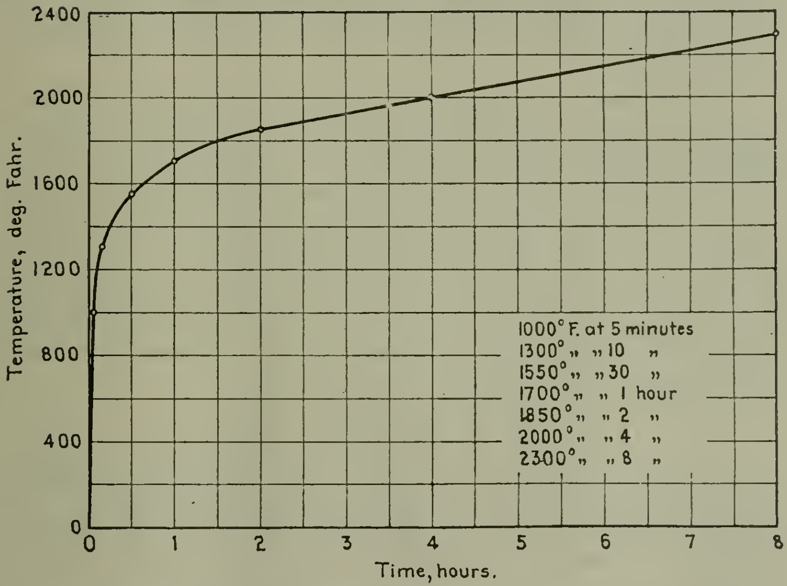

FIG. 1.—Standard Time-Temperature Control Curve for Fire Tests of Material and Construction.

III. TEST STRUCTURES.

Test Structures

4. (*a*) The test structure may be located at any place where all the necessary facilities for properly conducting the test are provided.

(*b*) Entire freedom is left to each investigator in the design of his test structure and the nature and use of fuel, provided the test requirements are met.

IV. TEST SAMPLES.

Test Samples.

5. The material or construction constituting the test sample shall be truly representative of the regular practice.

V. CONDUCT OF FIRE TESTS.

Fire Test. 6. The fire test on the sample with its applied load, if any, shall be continued until failure occurs, or until it has withstood the test conditions for a period equal to 1¼ times that for which classification is desired.

Fire Stream Test. 7. A second test with duplicate sample shall be made to determine the effect of a hose stream on a sample under fire test, the water being applied at the end of a period equal to three-fourths of that for which classification is desired, but not later than one hour after the beginning of the test; except that for classification periods of one-half hour or less the fire stream test may be omitted.

Application of Water. 8. The size of nozzle, water pressure and time of water application shall be as indicated in Table I. The hose stream shall be first directed at the middle of the sample and then at all parts of the exposed faces, changes in direction being made slowly.

Loading. 9. For any material or construction intended to carry load other than its own weight, the full rated safe working load shall be applied during the entire fire test, also during the fire stream test. After completion of the fire stream test, the sample shall be subjected to excess loading as prescribed under specifications for the different structural parts.

VI. FLOOR AND ROOF TESTS.

Size of Sample. 10. For floor and roof tests the sample shall be of such a size that the minimum span of the supporting beams of the floor arch shall be 12 ft., and the supporting beams and girders shall have a clearance of at least 8 in. from the walls of the test structure.

Time of Testing. 11. The floor or roof may be tested as soon after construction as desired, but within 40 days. Artificial drying will be allowed if desired.

Plastering. 12. If the construction is to be plastered in practice, the sample shall be plastered in the same manner.

Loading. 13. The floor or roof shall be loaded in a manner to develop in each member of the construction stresses equal to the maximum safe working stress allowed in the material of the member.

Requirements. 14. The test shall not be regarded as successful unless the following conditions are met:

(*a*) The floor or roof shall have sustained safely the full rated safe working load during the fire test without passage of flame, for a period equal to 1¼ times that for which classification is desired.

(*b*) The floor or roof shall have sustained safely the full rated safe working load during the fire stream test as prescribed in Sections 7 and 8, without passage of flame, and after its completion shall sustain a total load equal to the dead load plus 2½ times the live load for which the construction is designed.

VII. NON-BEARING PARTITION TESTS.

Size of Sample. 15. For partition tests the area of the sample shall be not less than 100 sq. ft. and no dimension less than 9 ft.

Determination of Temperatures. 16. Temperatures on the outer surface of the partition shall be read by not less than five thermometers, symmetrically disposed and placed against the surface of the partition with their bulbs properly protected against radiation of heat.

TABLE I.

Parts of Structure.	Type of Protection.	Size of Hose Nozzle, in.	Water Pressure at Nozzle, lb.	Time of Application min.
Floors and Roofs	4 hour	1⅛	50	10
	2 "	1⅛	50	5
	1 "	1⅛	50	2.5
	½ "	1⅛	30	1
	¼ "	1⅛	15	1
Walls, Columns and Partitions	4 "	1⅛	50	5
	2 "	1⅛	30	3
	1 "	1⅛	30	2.5
	½ "	1⅛	30	1
	¼ "	1⅛	15	1

Position of Nozzle. 17. The distance of the nozzle from the partition during the application of water shall be not more than 20 ft. when the hose stream is applied approximately normal to the surface of the partition, which distance shall be reduced by 1 ft. for each deviation of 10 deg. of angle from the normal when the hose stream is applied at an angle to the surface of the partition.

Requirements. 18. The test shall not be regarded as successful unless the following conditions are met:

(*a*) The partition shall have withstood safely the fire test for a period equal to 1¼ times that for which classification is desired.

(*b*) The partition shall have withstood the fire stream test as prescribed in Sections 7 and 8.

(*c*) No flame shall have passed through the partition during the prescribed fire period.

(*d*) Transmission of heat through the partition during the prescribed fire period shall not have been such as to raise the temperature on its outer surface in excess of 300° F.

(*e*) The partition shall not have warped or bulged or disintegrated under the action of fire or water to such an extent as to be unsafe.

EDITORIAL NOTE.

Specifications for fire tests of columns will be formulated when the joint investigation on that subject, now in progress, under direction of the Underwriters' Laboratories, the U. S. Bureau of Standards, and the Associated Factory Mutual Fire Insurance Companies has been completed. It is also planned to prepare fire test specifications for other structural members when sufficient data have been acquired to warrant such procedure.

STANDARD METHOD OF TEST
FOR
REFRACTORY MATERIALS UNDER LOAD AT HIGH TEMPERATURES.

Serial Designation: C 16 – 20.

This method is issued under the fixed designation C 16; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1917; ADOPTED IN AMENDED FORM, 1920.

1. The object of this test is to determine the resistance of the specimen to deformation at a specified temperature for a specified time, when subjected to a compressive load of 25 lb. per sq. in. (1.765 kg. per sq. cm.). **Object.**

2 The apparatus consists essentially of a furnace and loading device It shall be constructed in accordance with Figs. 1 and 2. **Apparatus.**

(*a*) The furnace shall be cylindrical in form, 18 in. (457 mm.) in internal diameter, as shown in Fig. 1 (Plate II).

(*b*) The heating shall be done with gaseous or oil fuel and compressed air, using not less than two burners located tangentially and so arranged that no flame can impinge upon the test specimen. The burners shall be such as will insure a uniform temperature in all parts of the furnace and be under complete control.

(*c*) The method of loading shown in Fig. 1 shall be used, and the details shall be such as will insure accuracy in the applied load and freedom from eccentric loading, both in the original application and during the testing. It is advantageous to make the cross-beams as light as possible, so that the greater portion of the load may be concentrated in the weights.

(*d*) The temperature may be measured either with a calibrated platinum-rhodium thermo-couple, encased in a double protecting tube with the junction not more than 1 in. (25 mm.) from the side or edge of the specimen and approximately opposite the center; or with some form of optical pyrometer that has been calibrated against a thermo-couple in the furnace. If the thermo-couple is used, the cold-end temperature should be kept constant in melted ice. A recording form of indicator is recommended where possible.

Test Specimen. 3. The test specimen shall consist, whenever possible, of a standard 9-in. brick placed vertically on end. In the case of blocks or shapes, sections approximately 9 by 4½ by 2½ in. (228 by 114 by 64 mm.) shall be cut, utilizing as far as possible existing plane surfaces. The ends of the specimen shall be either ground so that they are parallel and perpendicular to the vertical axis, or if this is impossible, shall be bedded in a neutral cement, so that the specimen is perpendicular to the base of the furnace.

TABLE I.—TEMPERATURE TO BE ATTAINED AT TIME SPECIFIED.

ALL TEMPERATURES IN DEGREES CENTIGRADE.

Time.	Silica.	Fire Clay.		
		Heavy Duty.	Moderate Duty.	Light Duty.
Hr. Min.				
15	40	160	160	160
30	80	280	280	280
45	140	400	400	400
1 0	200	500	500	500
15	260	620	595	570
30	290	720	685	640
45	300	815	770	700
2 0	310	900	850	755
15	320	980	920	810
30	385	1045	990	860
45	490	1100	1050	905
3 0	590	1150	1100	950
15	695	1195	1145	985
30	800	1235	1185	1020
45	900	1270	1220	1050
4 0	1000	1300	1250	1075
15	1100	1330	1275	1090
30	1200	1350	1300	1100
45	1250	1350	1300	1100
5 0	1300	1350	1300	1100
15	1350	1350	1300	1100
30	1380	1350	1300	1100
45	1410	1350	1300	1100
6 0	1440	1350 (End)	1300 (End)	1100 (End)
15	1470			
30	1500			
45	1500			
7 0	1500			
15	1500			
30	1500			
45	1500			
8 0	1500 (End)			

STANDARD METHOD OF TEST FOR REFRACTORY MATERIALS

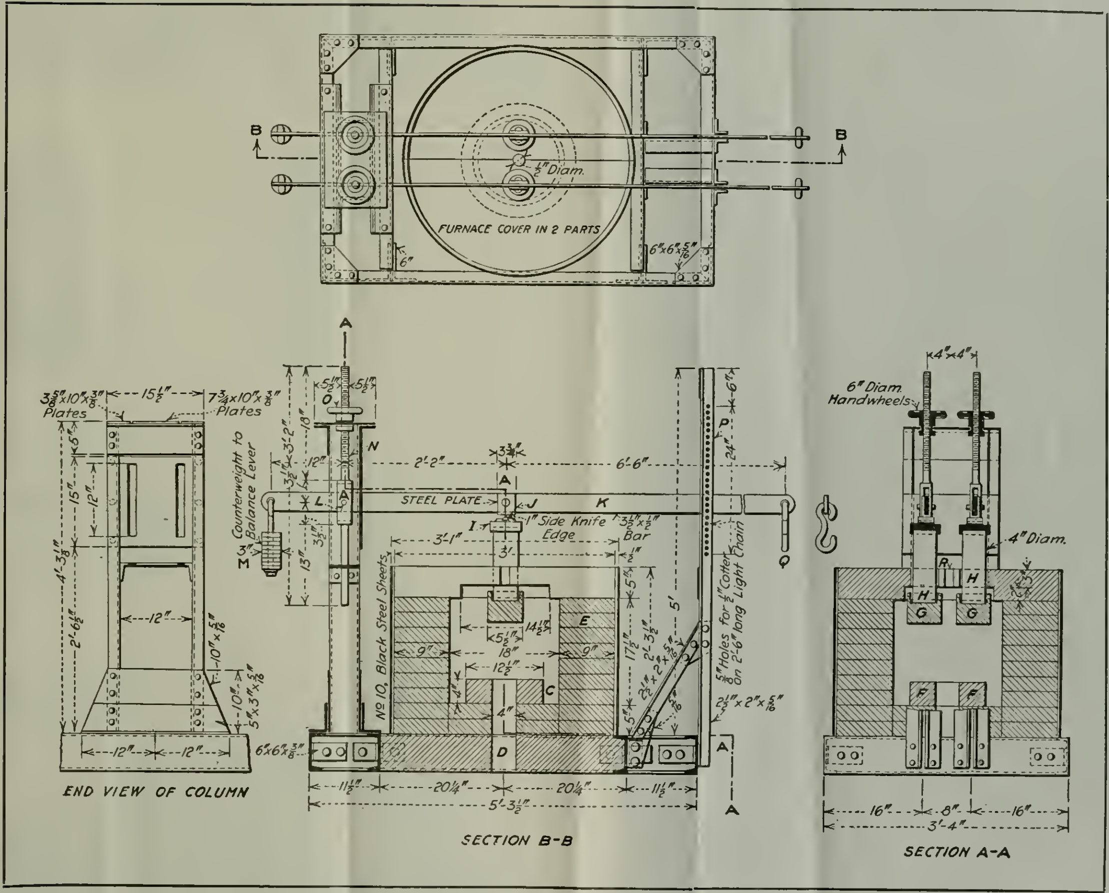

FIG. 1.—Apparatus for Testing Refractory Materials under Load at High Temperatures.

(By courtesy of *Metallurgical and Chemical Engineering.*)

The test specimen shall be measured before testing, making not less than five observations in each direction to within ±0.02 in. (0.5 mm.). The average dimensions shall be reported, and the cross-section calculated.

Starting the Test.

4. The test specimen shall occupy approximately the center of the furnace and should rest on a block of some highly refractory material, having a minimum expansion or contraction. A silicon-carbide brick has been found satisfactory. At the top of the test specimen a block of similar highly refractory material should be placed, extending through the furnace top to receive the load.

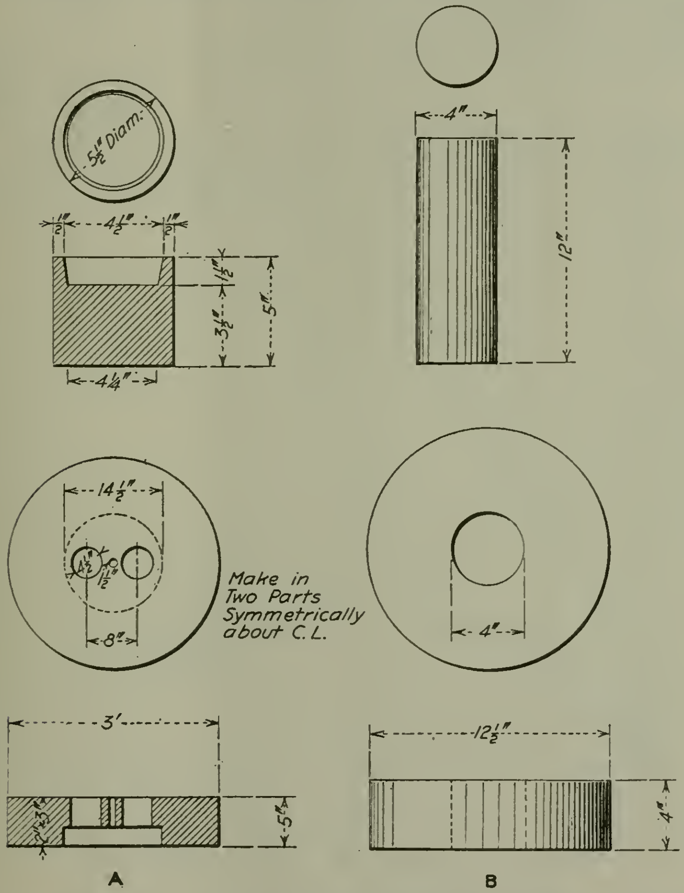

FIG. 2.—Special Shapes Required for Furnace.

(By courtesy of *Metallurgical and Chemical Engineering*.)

NOTE.—Gross errors which may more than double the contraction will result if the specimen is not set perpendicular to the base of the support or if the load is eccentrically applied.

Heating.

5. The rate of heating shall be in accordance with the requirements of Table I and the time-temperature curves of Fig. 3, which give the rate and time of heating suggested for different grades of material.

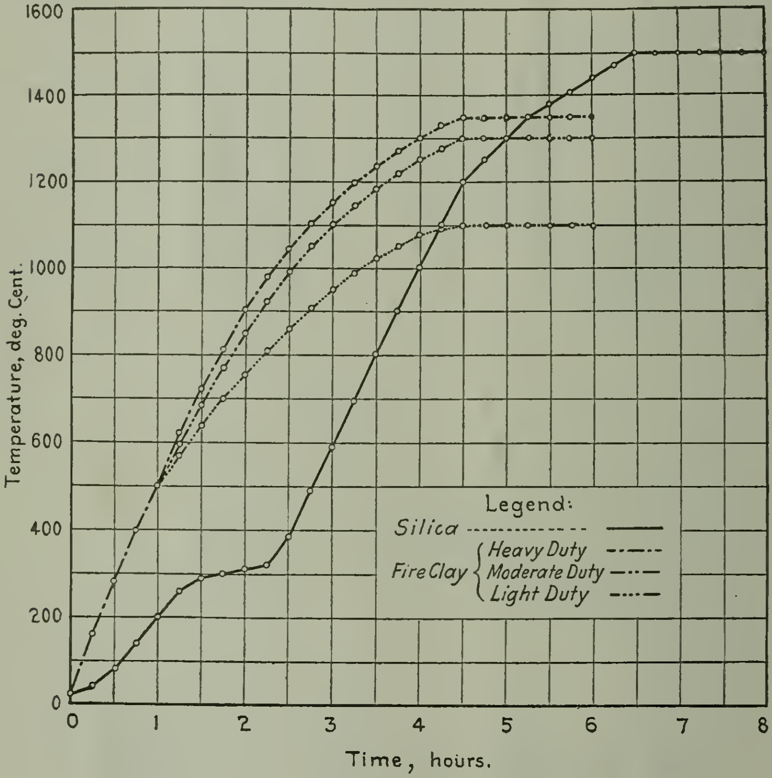

FIG. 3.—Time-Temperature Curve for Load Test.

Loading.

6. (*a*) The load is calculated from the average cross-section as determined on the untested specimen and the requirement of the test. It is recommended that for general purposes, 25 lb. per sq. in. (1.765 kg. per sq. cm.) be used.

(*b*) The additional masses required to give the desired loading should be equally distributed on each side of the beam.

Completing the Test.

7. (*a*) At the expiration of the time of heating, the supply of heat shall be stopped and the furnace allowed to cool, during

not less than 5 hours before removing the load and examining the test specimen.

NOTE.—The specimen shall be examined immediately after the heating is stopped for evidences of cracking and spalling, as such defects may develop later due to the rapid cooling of the furnace.

(*b*) After the test specimen has cooled to the room temperature, it shall be remeasured as before described, and the change in length recorded and reported as percentage of the original length.

NOTE.—It is recommended that a photograph be made of the specimen before and after testing, as yielding valuable information at a minimum time and expense.

STANDARD METHOD OF TEST

FOR

POROSITY AND PERMANENT VOLUME CHANGES IN REFRACTORY MATERIALS.

Serial Designation: C 20 – 20.

This method **is issued under the fixed designation C** 20; **the final** number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1918; ADOPTED, 1920.

Object. 1. The object of this test is to determine the porosity and permanent volume changes in refractory materials when heated to series of specified temperatures.

Preparation of Test Specimens. 2. (*a*) The sample shall consist of at least seven standard-size bricks.

(*b*) Test specimens measuring 2½ by 2½ by 1¼ in. shall be cut so as to remove the original surfaces of the bricks; for this a "cut off" grinding wheel is recommended. There should be five test specimens for each of the seven heat treatments specified in Section 4 or 35 test specimens for each kind of brick. The test specimens shall be brushed or washed free from all adhering dust and marked serially with a refractory stain, for which 5-per-cent cobalt-kaolin mixture is suggested.

Procedure. 3. After the test specimens have been cut and cleaned, they shall be dried and the volumes and porosity of each obtained as described in Sections 5 and 6. They shall be heated as specified in Section 4, and the changes in volume and porosity Determined.

Burning. 4. (*a*) Dry the test pieces prior to placing in the kiln.

(*b*) Raise the temperature as rapidly as is consistent with even heat distribution to 1200° C. From 1200° C. raise the temperature at the rate of 30° per hour, drawing samples at each 50° interval from 1200 to 1500° C.

(*c*) If it is possible and the number of brands being tested warrant, it is best that separate burns to each temperature be made and the kiln sealed and allowed to cool by radiation. In case separate burns cannot be made, the five test specimens from each temperature increment should be covered with hot sand immediately on being drawn; or placed in a supplementary furnace and kept at about 500° C. until all drawings are completed, and then cooled with the furnace sealed to cool wholly by radiation.

Method of Obtaining Data.

5. (*a*) The test specimens shall be cleaned from adhering or loosely attached pieces and particles, care being taken not to alter the exterior volume as originally prepared for this test.

(*b*) The test specimens shall be heated if necessary to 110° C. to remove moisture, and their dry weight (D) obtained to 0.10 g.

(*c*) The test specimens shall be placed in kerosene of known density (δ) under a vacuum of 24 in. for 4 hours at 25° C. and cooled to room temperature while yet immersed.

(*d*) When cool, each test specimen shall be weighed suspended in kerosene at 25° C. to determine its *Suspended Weight* (S), in grams.

(*e*) The *Saturated Weight* (W), in grams, of each test specimen shall be obtained immediately after obtaining the suspended weight, by drying lightly with a kerosene-moistened towel to remove the excess kerosene and then weighing in air.

(*f*) The *Exterior Volume* (V), in cubic centimeters, of each test specimen is obtained by subtracting the suspended weight (S) from the saturated weight (W), and dividing by the density (δ) of the kerosene. Thus,

$$V = \frac{W - S}{\delta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

(*g*) The *Actual Volume of Open Pores* (V_1), in cubic centimeters, is obtained by subtracting the dry weight (D) from the saturated weight (W), and dividing by the density (δ) of the kerosene. Thus:

$$V_1 = \frac{W - D}{\delta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(*h*) The *Apparent Specific Gravity* (T_1) of that portion of the test specimen which is impervious to liquid is obtained by dividing the dry weight by the difference between the dry and suspended weights, and multiplying by the density of the kerosene. Thus,

$$T_1 = \frac{D}{D - S}\delta \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

(*i*) The *True Specific Gravity* (T) of the wholly solid or burned clay portion is obtained by crushing a portion of the dried test specimen to 120-mesh powder and determining the displacement at 25° C. under 24 in. vacuum, of a 20-g. sample in a 50-cc. straight-wall pyknometer using kerosene, and correcting for density of the kerosene.

(*j*) The *Volume of Sealed Pores* (V_2), in cubic centimeters, is obtained by subtracting the quotient of dry weight (D) divided by true specific gravity (T) from the volume of the impervious portion of the test specimen; or

$$V_2 = \frac{(D - S)}{\delta} - \frac{D}{T} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

(*k*) The *Volume Shrinkage* is obtained by subtracting the volumes, that is, the values of $\frac{W - S}{\delta}$, before and after the heat treatment.

Basis of Reference for the Data.

6. To show progressive changes in the several volumes, refer all volumes back to the original exterior volume of the test specimen as 100. This is done by multiplying all volumes by the factor $100/V$, in which V is the exterior volume of the test specimen prior to the subjection to heat treatment.

The volume data should be determined for each test specimen and multiplied by the above factor to reduce all volumes for each test specimen to terms of 100 original exterior volumes of that test specimen before the average of the five for each heat treatment is calculated.

STANDARD METHOD OF TEST
FOR
SOFTENING POINT OF FIRE-CLAY BRICK.

Serial Designation: C 24 – 20.

This method is issued under the fixed designation C 24; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED, 1920.

Object.

1. The object of this test is to determine the softening point of fire-clay brick, by comparison of test cones with standard Orton pyrometric cones heated in a suitable furnace.

Preparation of Sample.

2. A 1-kg. (2-lb.) sample shall be taken by chipping off approximately equal portions from the corners of the brick. These fragments shall be reduced in size by means of rolls or a jaw crusher adjusted to pass a lump 6 mm. ($\frac{1}{4}$ in.) in diameter. They shall be mixed thoroughly, and the amount of material reduced to about 250 g. (5 lb.) by quartering. A magnet shall be repeatedly passed through the crushed material until all particles of metallic iron are removed. This portion shall be ground in a porcelain or agate mortar to pass a 60-mesh Standard sieve.[1] In order to avoid excessive reduction of the fines, they shall be removed frequently during the process of reduction by throwing the sample on the sieve and continuing the grinding of the coarser particles until all the sample will pass through the sieve.

Preparation of Test Cones.

3. (*a*) The sample thus prepared shall be thoroughly mixed and after the addition of sufficient dextrine or glue and water, shall be formed into test cones in a metal mold in the shape of tetrahedrons measuring 5 mm. ($\frac{3}{16}$ in.) on the sides at the base and 25 mm. (1 in.) high.

(*b*) When dry the test cones may be subjected to a preliminary burn at a temperature not exceeding 1300° C. (2372° F.) for the purpose of sintering them into a firm condition to permit handling.

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[1] Diameter of wire 0.185 mm., opening 0.25 mm.

Mounting. 4. The test cones shall be mounted on plaques of refractory material of such a composition as will not affect the fusibility of the cones.[1] They shall be mounted with the base embedded approximately 1 mm. (0.04 in.) in the plaque and the face of one side inclined at an angle of 75 deg. with the horizontal. The arrangement with respect to the Orton cones shall be substantially as shown in Fig. 1, that is, alternating with the Orton cones in such a way that Orton cones of successive numbers will be placed opposite each other. The plaque may be any convenient size and shape and may be biscuited before using, if desired.

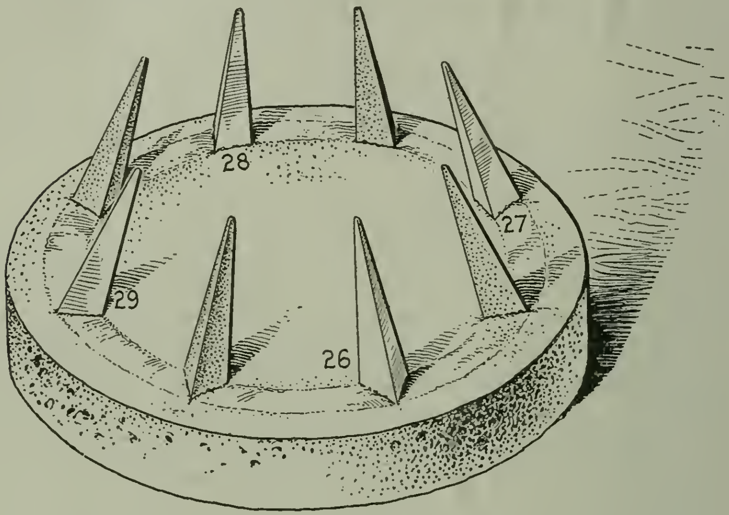

FIG. 1.

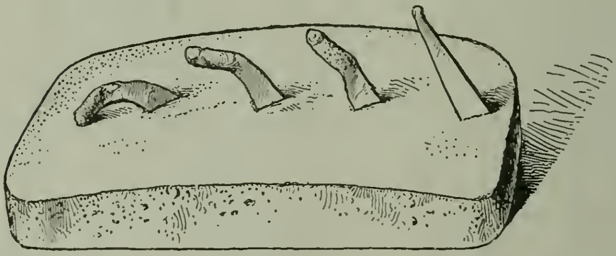

FIG. 2.

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[1] A mixture of equal parts of a highly refractory clay, such as a good grade of china clay, and fused alumina which will pass a 100-mesh sieve, has been found satisfactory.

Heating.

5. (*a*) The heating shall be done in a suitable furnace at a rate not greater than 15° C. (27° F.) per minute, nor less than 10° C. (18° F.) per minute after cone No. 1 is reached, or as nearly within these limits as possible.

(*b*) That type of furnace in which a neutral or oxidizing atmosphere may be maintained is to be preferred. Excessive reducing conditions should be avoided. Care should be taken that the flame does not strike directly against the cone or cone plaque. The furnace should be tested at intervals for the determination of the uniformity of the distribution of the heat.

Softening Point.

6. (*a*) The softening of the cone will be indicated by the top bending over and assuming the position shown in Fig. 2. The bloating, squatting or unequal fusion of small constituent particles should always be reported. The softening point shall be reported in terms of Orton cones and shall be that cone which most nearly corresponds in time of softening with the test cone. If the test cone softens later than one Orton cone but earlier than the next Orton cone and approximately midway between, the softening point shall be reported thus: Cone No. 31–32.

(*b*) If the test cone starts bending at an early cone but is not down until a later cone, the fact should be reported.

STANDARD METHODS

OF

ULTIMATE CHEMICAL ANALYSIS OF REFRACTORY MATERIALS, INCLUDING CHROME ORES AND CHROME BRICK.

Serial Designation: C 18 – 21.

These methods are issued under the fixed designation C 18; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted in Amended Form, 1920; Revised, 1921.

Prefatory Note.—It will be understood that the making of a complete silicate analysis is a difficult procedure requiring a wide knowledge of the chemistry involved in the operations, and a thorough training in carrying out the work. A skilled analyst of good training is therefore required to do the work. The descriptions here given cover the vital points of procedure, but frequent reference in regard to the details of the various manipulations must be made to *Bulletin No. 422*, United States Geological Survey on "Analysis of Silicate and Carbonate Rocks," by W. F. Hillebrand; also, to "Treatise on the Ceramic Industries," Vol. 1 (1913), by J. W. Mellor; and to similar publications.

I. GENERAL REFRACTORIES.

I. GENERAL CONSIDERATIONS.

Grinding of Sample.

1. The sample shall be crushed in a hardened tool-steel mortar, using a pestle of the same sort. Fine grinding shall be done in an agate mortar, either by hand, or by a mechanical sample grinder of the McKenna, Carling or similar type, so constructed as to prevent the introduction of impurity.

Statement of Analysis.

2. Moisture shall be determined in the sample in its ordinary air-dried condition, and all other percentage compositions shall be calculated to a moisture-free basis. Whenever a sample is weighed out for any determination, a moisture determination shall also be made. If preferred, the sample may be dried in a weighing bottle, from which the required samples shall be weighed out.

Checking Results.

3. In all cases, check determinations shall be made, and the results shall be redetermined if satisfactory checks are not obtained. It shall be considered satisfactory if the differences between check determinations do not exceed the following limits:

For silica or other constituent amounting to 30 per cent or over	0.3 per cent
For alumina or other constituent amounting to 10–30 per cent	0.2 per cent
For any other constituent amounting to under 10 per cent	0.1 per cent

These figures are stated in terms of the whole sample as 100 per cent.

II SOLUTIONS REQUIRED.

Concentrated Acids.

4. The acids referred to as concentrated shall be of approximately the following specific gravities:

Hydrochloric Acid (HCl)	1.20
Sulfuric Acid (H_2SO_4)	1.84
Nitric Acid (HNO_3)	1.42

Ammonium Carbonate.

5. Dissolve 1.5 g. of ammonium carbonate in 50 cc. of cold water.

Ammonium Chloride.

6. Dissolve 107 g. of NH_4Cl in 1000 cc. of warm water.

Ammonium Nitrate.

7. Neutralize 20 cc. of concentrated HNO_3 with NH_4OH and dilute to 1000 cc. Test with litmus; the solution shall not be acid.

Ammonium Oxalate.

8. Dissolve 1 g. of ammonium oxalate in 50 cc. of water, heating gently.

Standard-Titania Solution.

9. The strength of the final standard titania solution shall be 1 cc. = 0.0001 g. TiO_2. To prepare the solution weigh out in a platinum crucible an amount of potassium titanium fluoride (K_2TiF_6) sufficient to make from ½ to 1 liter of "stock solution" in which 1 cc. = 0.001 g. TiO_2. Evaporate several times with H_2SO_4 without taking to dryness, thus driving out all fluorine. Take up the residue with water containing enough H_2SO_4 to make at least 5 per cent of the solution, when finally diluted to the standard solution strength. To standardize the stock solution take out two 50-cc. portions, dilute, boil and precipitate with ammonia. Filter, wash with hot water until free from alkali, ignite, blast and weigh. The duplicate should check very closely. From the weight of titania thus determined calculate

the strength of the stock solution. The standard solution to be used is obtained from the stock solution by diluting until 1 cc. = 0.0001 g. (TiO_2).

Standard Potassium-Permanganate Solution.

10. Dissolve about 0.4 g. (a little less) of $KMnO_4$ in 1 liter of water and check against an iron solution of known purity and strength. Dilute the solution until 1 cc. = 0.001 g. Fe_2O_3

The ordinary chemical iron wire is not sufficiently pure for this use. If preferred the solution may be standardized against sodium oxalate, a pure form of which is prepared especially for such work by the U. S. Bureau of Standards, Washington, D. C.

III. METHODS.

MOISTURE.

Moisture.

11. To determine moisture, heat approximately 1 g. of the sample at a temperature not under 105 nor over 110° C., to constant weight.

LOSS ON IGNITION.

Ignition Loss.

12. To determine loss on ignition, heat about 1 g. of the sample over a blast lamp or in an electric furnace at 900 to 1000° C., to constant weight. Ignition loss may be determined in the sample from which the moisture has been removed. The percentage of ignition loss is calculated to a moisture-free basis.

SILICA.

Silica.

13. To determine silica, weigh out approximately 0.5 g. of the sample and mix with 5 g. of Na_2CO_3. Put a little Na_2CO_3 in the bottom of the crucible before introducing the mixture, and then cover the mixture with a little more Na_2CO_3. Fuse over a Meker burner or blast lamp until complete solution is obtained. Cool the fusion and as it solidifies, rotate the crucible to spread the mass up the side walls. Dissolve the fusion in about 100 cc. of water in a platinum or porcelain evaporating dish. Add about 20 cc. of concentrated HCl, introducing it slowly by means of a pipette, keeping the dish covered with a watch glass. Evaporate to dryness and heat until the fumes of HCl are gone. Add about 5 cc. of concentrated HCl and 30 to 40 cc. of water. Warm on a water bath for 10 to 15 minutes and break up the lumps. Decant the clear liquid onto a filter paper and collect the filtrate in a 400-cc. beaker. Add more HCl and water to the evaporating dish, warm again and decant. Repeat this a third time.

Finally transfer the contents of the dish to the filter paper.

Wash with cold water until silver nitrate shows no chlorides to be left. Transfer the filtrate to the original evaporating dish, evaporate again to dryness, take up with a little HCl and water, transfer to a new filter paper and wash as before. Transfer both silica precipitates to a platinum crucible. Ignite carefully over a Bunsen flame until the filter paper is burned off, then blast for about 30 minutes; cool and weigh. Repeat blasting for 5 minutes, weigh again and repeat until constant weight is obtained.

To the residue in the crucible add about 5 cc. of water and 5 drops of H_2SO_4. Add HF drop by drop at first, and then slowly until the crucible is almost one-half filled. Warm on a hot plate until almost dry, add 2 or 3 cc. more of HF and evaporate to dryness. Heat the crucible to bright redness and then blast for 5 minutes. Cool and weigh and repeat blasting to constant weight. The loss in weight from the original silica residue represents the actual silica content (SiO_2), except for that part of silica which is later recovered from alumina, etc. The residue from the HCl evaporation is left in the crucible and the total precipitate of alumina, etc., is added to this same crucible in which it is ignited and weighed.

ALUMINA.

14. Regarding the determination of alumina, reference should be made to *Scientific Paper No. 286* of the U. S. Bureau of Standards by Dr. Blum on "Determination of Alumina as Oxide." **Alumina.**

To determine alumina, to the filtrate from the silica determination, add about 10 cc. of NH_4Cl solution and heat to boiling. Then add NH_4OH very slowly and with constant stirring until there is a slight excess. The NH_4OH must be free from CO_2. Filter hot and rapidly, and wash four times by decantation with hot solution of ammonium nitrate. Carefully wash the precipitate from the filter paper into a beaker, using hot water. Dissolve the precipitate in hot dilute HCl. Repeat the precipitation with NH_4Cl and NH_4OH. Decant four times as before, using hot ammonium nitrate. Transfer to the filter paper and wash with hot ammonium nitrate until the washings are free from chlorides when tested by silver nitrate. Evaporate the filtrate nearly to dryness, add a little NH_4OH and continue the evaporation. Keep the solution alkaline to coagulate any iron and aluminum hydroxides. Transfer the precipitate to a filter paper and wash thoroughly. Transfer the moist filter paper to the platinum crucible containing the residue from the silica. Burn off the filter paper and blast the precipitate. Repeat blasting and weighing to a constant weight.

IRON OXIDE.

Iron Oxide. 15. To determine iron oxide, fuse the ignited alumina precipitate with about six times its weight of potassium pyrosulfate or potassium bisulfate. Avoid sputtering. Heat carefully to redness and continue heating until the residue is all dissolved. Cool. Dissolve in warm water and add about 10 cc. of dilute H_2SO_4 (1:5). Evaporate to a small volume. Then heat to a higher temperature until copious fumes of H_2SO_4 are evolved. Sufficient H_2SO_4 should be present to form a pasty mass when cooled. Take up with water, filter off, wash, ignite and weigh the silica as before and evaporate with HF as before. The loss in weight is extra silica to be added to the original silica determination and subtracted from the alumina. Fuse the residue with a little potassium pyrosulfate or potassium bisulfate, and add the solution of this cake to the main solution. Transfer the total filtrate to a 250-cc. graduated flask and dilute to 250 cc. ,mixing thoroughly. Draw off 50 cc. of this solution and reserve for titania determination. Pass the remaining 200 cc. through a Jones reductor, or otherwise reduce the solution with pure zinc and H_2SO_4. To the solution add 3 cc. of 10-per-cent $CuSO_4$ solution and titrate with standard $KMnO_4$ solution (1 cc. equivalent to 0.001 g. Fe_2O_3), until a faint pink tinge is seen. If Jones reductor or similar apparatus is used, subtract the $KMnO_4$ equivalent, which has previously been determined on blank samples run through the apparatus. From the result, calculate the iron as Fe_2O_3.

TITANIA.

Titania. 16. To determine titania, place in a small Nessler tube the 50 cc. of filtrate previously set aside for titania determination, and fill the tube up to the graduation mark. Add 1 cc. of H_2O_2 (free from fluorine) and shake well. The color of this solution is now compared in any standard color comparator with the color of a known standard solution, preferably of such strength that 1 cc. equals 0.0001 g. of titanium dioxide (TiO_2). To make the comparison, put 10 cc. of this standard solution into a second small Nessler tube and dilute with water from a burette until the color is matched. Note the amount of water added and calculate the percentage of TiO_2 in the sample.

LIME.

17. To determine lime, evaporate the filtrate from the alumina precipitation to about 250 cc. While still boiling add about 5 cc. of acetic acid. Meanwhile, dissolve about 1 g. of oxalic acid in a little hot water and add to the solution. In about 5 minutes add a slight excess of NH_4OH and boil until precipitation is complete. Cool thoroughly and filter. Wash three times by decantation with dilute NH_4OH (1 : 10) or a 1-per-cent solution of ammonium oxalate. Dissolve the precipitate by adding about 50 cc. of dilute HNO_3 (1 : 5). Again add a slight excess of NH_4OH and a few drops of oxalic-acid solution. Boil well and let stand a couple of hours to cool. Filter and wash as before. Transfer the precipitate to a platinum crucible, carefully burn off the paper and ignite over a blast lamp for about 10 minutes. Cool and weigh quickly. Repeat the blasting to constant weight. The increase in weight of crucible is calcium oxide. **Lime.**

MAGNESIA.

18. To determine magnesia, add to the filtrate from lime precipitation about 2 g. of sodium-ammonium-phosphate dissolved in 15 cc. of water. Stir vigorously and while stirring add drop by drop about one-third of the volume of the solution of NH_4OH. Let stand 12 to 24 hours. Filter and wash the precipitate with dilute NH_4OH (1 : 10). Discard the filtrate. Wash the precipitate until the washings show no discoloration when tested with silver nitrate. Redissolve the precipitate in warm dilute HNO_3 (1 : 5), using about 50 cc., and collect in a beaker. Precipitate and wash as before. Collect the precipitate on a Gooch asbestos crucible. Dry slowly and then heat over a Meker burner for about 10 minutes; cool and weigh. Re-ignite to constant weight. **Magnesia.**

The $Mg_2P_2O_7$ is never pure, being contaminated by small amounts of calcium, barium, aluminum, iron, manganese, etc., but in the analysis of refractories this error is negligible, and correction for these impurities is not required unless previously agreed upon.

ALKALIES.

19. To determine alkalies, the J. Lawrence Smith method shall be used. Weigh out about 0.5 g. of the sample and mix well with 0.5 g. of NH_4Cl and 3 g. of $CaCO_3$. Transfer to a **Alkalies.**

platinum crucible, placing about 0.5 g. of $CaCO_3$ in the bottom of the crucible and a similar amount over the top of the mixture. Heat gently over a low flame for about 15 minutes to volatilize NH_4Cl. Then raise the temperature until the lower three-quarters of the crucible is dull red. Hold this temperature for about one hour. Cool, take up with about 50 cc. of water and heat over a water bath, adding water to replace that lost by evaporation. Break up any lumps with a small pestle. Decant the clear liquid through a filter paper and wash four times by decantation. Then transfer the residue to the filter. Wash until silver nitrate shows only a very faint turbidity. To the filtrate add NH_4OH and ammonium carbonate and heat to boiling. Filter and again digest the precipitate with NH_4OH and ammonium carbonate. Filter and allow the filtrate to collect with the previous filtrate, then evaporate to dryness in a platinum or porcelain dish. Remove ammonium salts by gentle ignition in a moving flame. Treat with water and remove the last trace of lime by adding ammonium oxalate to the boiling solution and let stand over night. Filter, evaporate to dryness, ignite gently and allow to cool. Then moisten the residue with HCl, evaporate again to dryness, ignite gettly and weigh. Dissolve in water. Ignite and weigh any insoluble residue, deducting this from the alkali chlorides.

Dilute the solution of the mixed chlorides and add hydrochloroplatinic acid in amount equal to 0.3 cc. more than would be necessary if all chlorides were present as NaCl. Evaporate to a syrupy consistency. Cool and treat with a few cubic centimeters of 80-per-cent ethyl alcohol. Stir and decant through a weighed Gooch crucible. Treat again with 80-per-cent alcohol and decant. Repeat washing and decantation until the alcohol leaving the Gooch crucible is colorless and the precipitate appears golden yellow, not orange. Transfer the precipitate to the Gooch crucible, wash with 80-per-cent alcohol about six times and dry at 130° C. to constant weight. This residue is potassium chloroplatinate.

The oxides are calculated as follows:

Weight of potassium chloroplatinate $\times 0.3068 = KCl$.
Weight of potassium chloroplatinate $\times 0.1941 = K_2O$.
Total chlorides $- KCl = NaCl$.
$NaCl \times 0.5303 = Na_2O$.

II. CHROME ORES AND CHROME BRICK.

Sampling. 20. The sample shall be secured after the manner of any of the approved methods of sampling. If from ores or chrome-bearing refractories, it shall not be less than 10 lb., in small nut-size particles when sent to the laboratory. If from chrome brick, the sample shall consist of a small portion from the interior of from 15 to 25 bricks. This 10-lb. sample shall be crushed to pass a 20-mesh sieve and quartered until a sample of 100 g. is secured, which shall be ground to pass a 100-mesh sieve. From this portion, a smaller working sample shall be quartered and ground in an agate mortar to a very nearly gritless powder. In the case of hard burned brick or hard lump chrome ore the very fine grinding assists materially in solution of the sample.

Method. 21. Dry the fine, ground powder at 110° C. for not less than one hour. Cool in desiccator. Fuse 0.5 g. of the thoroughly dried sample in approximately 10 g. of fused potassium bi-sulfate in a platinum crucible. The usual cautions of a bi-sulfate fusion should be observed: that is, the flame turned very low so that the bi-sulfate just melts, increasing the flame so that the bi-sulfate remains in a liquid condition, very gradually increasing until the crucible reaches a dull red heat. The object of the slow heating is to retain the sulfuric acid, which is the effective part of the flux. The most refractory ores should be thoroughly fused in $1\frac{1}{2}$ to 2 hours. Remove the crucible from the burner and allow to cool in the air. The bi-sulfate melt will shrink from the crucible and may be removed easily in one cake. Dissolve the fusion in 200 cc. hot HCl (1 : 1), boiling until the solution acquires a clear, bright green color. Transfer the solution to a porcelain evaporating dish and evaporate to dryness on a water bath. Bake at exactly 120° C. until free from hydrochloric acid fumes. Moisten with hot HCl (1 : 1), evaporate on water bath and bake a second time at 120° C. Dissolve in 200 cc. hot dilute HCl (1 : 1), and filter out the silica. Ignite and weigh the silica in a platinum crucible. Add two drops concentrated H_2SO_4 and sufficient HF to remove all silica. Evaporate, ignite and weigh. The difference gives the amount of silica present in the sample. Should there be any appreciable residue left in the crucible it should be fused with a small amount of fused $KHSO_4$ and added to the filtrate from the silica.

Dilute the filtrate from the silica to about 500 cc. and precipitate iron, aluminum, chromium and titanium, if present, with NH_4OH, using care to have not more than two drops of

NH_4OH in excess in order to avoid solution of chromium and aluminum hydroxide in the alkaline solution. On account of the relatively large amount of magnesium that is usually present in chrome ores and chrome brick it is advisable to dissolve the precipitate in hot dilute HCl and precipitate a second time. Filter out the combined hydroxides and dissolve them on the filter paper with HNO_3, catching the solution in a porcelain casserole. Add a few crystals of $KClO_3$ and evaporate the nitric solution, adding a crystal of $KClO_3$ from time to time until the chromium is completely oxidized, which is indicated by a change from a dull green to a brilliant orange color. Dilute this solution with hot water and again precipitate with NH_4OH, filtering as before. The filtrate contains a large percentage of the chromium, while the residue on the filter consists of iron and aluminum hydroxides and titanium, if present. Repeat the oxidation two or three times until the filtrate from the iron and aluminum hydroxide precipitation shows no further traces of chromium. Concentrate and combine the filtrates containing chromium to approximately 500 cc. Add H_2SO_3 until the liquid changes from a bright orange to a brilliant green color and heat to boiling. Add NH_4OH to precipitate chromium as hydroxide, having not more than two drops in excess, as stated above. Filter, wash well with hot water, ignite and weigh as Cr_2O_3. The iron and aluminum and titanium hydroxides are ignited and weighed in a platinum crucible. Fuse the combined oxides with a small amount of $KHSO_4$, following the same precautions as mentioned above. Dissolve the fusion in dilute H_2SO_4, reduce with H_2S and titrate the iron with standard permanganate solution. Determine the titanium present by the colorimetric method, as described in Section 16. Subtract the combined amounts of Fe_2O_3 and TiO_2 from the total weight of the three oxides and thus determine Al_2O_3. If titanium is absent, reduce the iron with metallic zinc and titrate with K_2MnO_4, which is a little quicker method than the H_2S reduction.

To the combined filtrates from the precipitations of iron, aluminum, chromium and titanium hydroxides add bromine, allow to stand for a few minutes and then add sufficient NH_4OH to precipitate the manganese hydroxide. Boil to concentrate the manganese hydroxide if any be present. Filter, ignite and weigh as Mn_3O_4. In the filtrate from the manganese add NH_4OH and $(NH_4)_2C_2O_4$. Heat to boiling and when the calcium oxide has settled, filter with the usual precautions. The calcium oxide may be determined by ignition or by the volumetric method. (Refer to the determination of calcium oxide as described in Section 17.)

Evaporate the filtrate from the calcium oxalate to dryness with HNO_3 to remove the excess of ammonium salts. Dissolve the residue in hot water, filter, allow to cool and determine MgO as described in Section 18.

Determine alkalies by the J. Lawrence Smith Method, as described in Section 19.

RAPID ROUTINE METHOD FOR THE ANALYSIS OF CHROME BRICK AND CHROME ORE.

Rapid Routine Method.

22. The sample shall be secured after the manner of any of the approved methods of sampling. If from ores or chrome bearing refractories it shall not be less than 10 lb. in small nut-sized particles when sent to the laboratory. If from chrome brick, the sample shall consist of a small portion from the interior of from 15 or 25 bricks. This 10-lb. sample shall be crushed to pass a 20-mesh sieve and quartered, until a 4-oz sample is secured, which shall be ground to pass a 100-mesh sieve. From this portion a smaller working sample shall be quartered and ground in an agate mortar to a very nearly gritless powder. In the case of hard burned brick or hard lump chrome ore the very fine grinding assists materially in solution of the sample. Dry the fine, ground powder at 110° C. for not less than 1 hour. Cool in desiccator.

CHROMIUM.

Chromium.

23. Fuse 0.5 g. of the sample in 8 to 10 g. of sodium peroxide in a nickel or porcelain crucible over a Bunsen burner, being careful not to heat too strongly. When fused, leach out with cold water, boil 15 minutes to decompose any sodium peroxide. Cool and add 100 cc. of H_2SO_4 (1:1). Cool to tap-water temperature and titrate with ferrous ammonium sulfate and potassium permanganate. Time 30 to 45 minutes.

SILICA AND IRON.

Silica and Iron.

24. Fuse 0.5 g. of the sample in a nickel crucible over a Bunsen burner. Leach out with cold water, make acid with HCl and evaporate to dryness. Take up with 200 cc. water and add 10 cc. HCl. Filter off silica and wash well with hot water and hot dilute HCl. For high silica a second evaporation is necessary.

The filtrate or combined filtrate is made alkaline with sodium hydroxide and about 5 cc. of bromine added. The mass is allowed to digest for $\frac{1}{2}$ hour on a steam bath. This oxidizes the iron and chromium, precipitates the iron and dissolves the chromium and aluminum. After precipitating the iron twice it is filtered off on an asbestos plug and washed well with hot water. This precipitate of iron may be dissolved off the plug with hot HCl (1:1) and determined by the stannous chloride reduction, and permanganate method.

A blank should be run in conjunction with this method and deductions made when necessary to determine the purity of the chemicals used.

STANDARD METHOD OF TEST
FOR
UNIT WEIGHT OF AGGREGATE FOR CONCRETE.

Serial Designation: C 20 – 21.

This method is issued under the fixed designation C 29; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1920; ADOPTED, 1921.

1. The unit weight of fine, coarse, or mixed aggregates for concrete shall be determined by the following method:

Apparatus. 2. (*a*) The apparatus required consists of a cylindrical metal measure, a tamping rod, and a scale or balance, sensitive to 0.5 per cent of the weight of the sample to be weighed.

(*b*) *Measures.* — The measure shall be of metal, preferably machined to accurate dimensions on the inside, cylindrical in form, water-tight, and of sufficient rigidity to retain its form under rough usage, with top and bottom true and even, and preferably provided with handles.

The measure shall be of $\frac{1}{10}$, $\frac{1}{2}$ or 1-cu. ft. capacity, depending on the maximum diameter of the coarsest particles in the aggregate, and shall be of the following dimensions:

Capacity, cu. ft.	Inside Diameter, in.	Inside Height, in.	Minimum Thickness of Metal, U. S. Gage.	Diameter of Largest Particles of Aggregate, in.
$\frac{1}{10}$	6.00	6.10	No. 11	Under $\frac{1}{2}$
$\frac{1}{2}$	10.00	11.00	No. 8	Under $1\frac{1}{2}$
1	14.00	11.23	No. 5	Over $1\frac{1}{2}$

(*c*) *Tamping Rod.*—The tamping rod shall be a straight metal rod $\frac{3}{4}$ in. in diameter and 18 in. long, with one end tapered for a distance of 1 in. to a blunt bullet-shape point.

Calibrating the Measure. 3. The measure shall be calibrated by accurately determining the weight of water at 16°.7 C. (62° F.) required to fill it. The factor for any unit shall be obtained by dividing the unit weight of water at

16°.7 C. (62° F.)[1] by the weight of water at 16°.7 C. (62° F.) required to fill the measure.

4. The sample of aggregate shall be room dry and thoroughly mixed.

Method. 5. (*a*) The measure shall be filled one-third full and the top levelled off with the fingers. The mass shall be tamped with the pointed end of the tamping rod twenty-five times, evenly distributed over the surface. The measure shall be filled two-thirds full and again tamped twenty-five times as before. The measure shall then be filled to overflowing, tamped twenty-five times, and the surplus aggregate struck off, using the tamping rod as a straight edge.

In tamping the first layer the rod should not be permitted to forcibly strike the bottom of the measure. In tamping the second and final layers, only enough force to cause the tamping rod to penetrate the last layer of aggregate placed in the measure should be used. No effort should be made to fill holes left by the rod when the aggregate is damp.

(*b*) The net weight of the aggregate in the measure shall be determined. The unit weight of the aggregate shall then be obtained by multiplying the net weight of the aggregate by the factor found as described in Section 3.

Accuracy. 6. Results with the same sample should check within 1 per cent.

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[1] The unit weight of water at 16°.7 C. (62° F.) is 62.355 lb. per cu. ft.

STANDARD METHOD
OF
MAKING AND STORING SPECIMENS OF CONCRETE IN THE FIELD.

Serial Designation: C 31 – 21.

These methods are issued under the fixed designation C 31; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1920; Adopted, 1921.

Scope. 1. The methods herein specified apply to molding and storing of test specimens of concrete sampled from concrete being used in construction.

Size and Shape of Specimen. 2. The test specimens shall be cylindrical in form with the length twice the diameter. In general a mold whose diameter is not less than four times the diameter of the largest size aggregate shall be used. (The sizes most commonly used are 6 by 12-in. and 8 by 16-in. cylinders.)

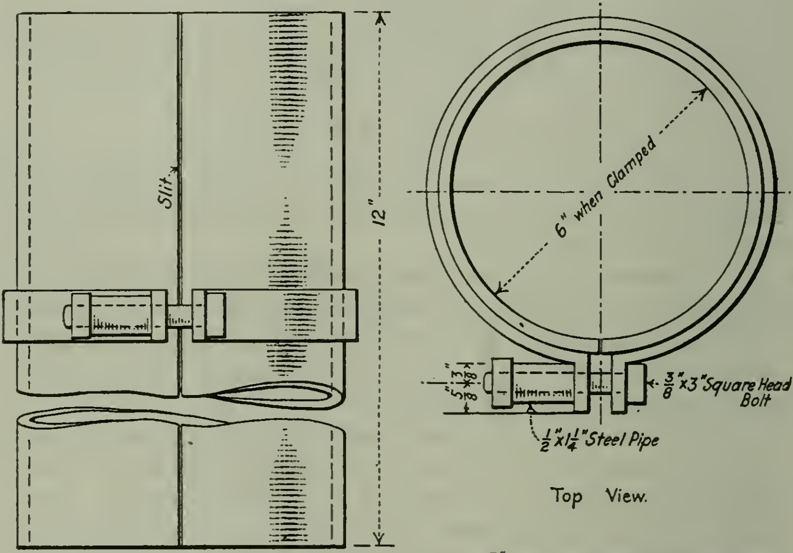
Molds. 3. (*a*) The molds shall be cylindrical in form, made of non-absorbent material, and shall be substantial enough to hold their form during the molding of the test specimens. They shall not vary in diameter more than $\frac{1}{16}$ in. in any direction, nor shall they vary in height more than $\frac{1}{16}$ in. from the height required. They shall be substantially water tight so that there will be no leakage of water from the test specimen during molding.

(*b*) Each mold shall be provided with a base plate having a plane surface and made of non-absorbent material. This plate shall be large enough in diameter to properly support the form without leakage. Plate glass or planed metal are satisfactory for this purpose. A similar plate should be provided for covering the top surface of the test specimen after being molded.

(*c*) Suggestions for suitable forms are shown in Figs. 1, 2 and 3.

Sampling of Concrete. 4. (*a*) Concrete for the test specimens shall be taken immediately after it has been placed in the work. All the concrete for each sample shall be taken from one place. A sufficient number of samples—each large enough to make one test specimen—shall be taken at different points so that the test specimens made from them will give a fair average of the concrete placed in that portion of the structure selected for tests. The location from which each sample is taken shall be noted clearly for future reference.

(*b*) In securing samples, the concrete shall be taken from the mass by a shovel or similar implement and placed in a large pail or other receptacle, for transporting to the point of molding.



Side View.

Top View.

Stock: $6\frac{3}{8}$" O.D. Cold-Drawn Seamless Steel Tubing; $\frac{3}{16}$" Walls. Make Narrow Slit along one Element. May also Use 6" Steel Water-Pipe, Machined Inside. Slit along one Element, so that when Closed will give 6" Inside Diameter.

FIG. 1.

Care shall be taken to see that each test specimen represents the total mixture of the concrete at that place. Different samples shall not be mixed together but each sample shall make one specimen.

Molding the Specimens. 5. (*a*) The pails or other receptacles containing the samples of concrete shall be taken as quickly as possible to the place selected for molding test specimens. To offset segregation of the concrete occurring during transportation, each sample shall be dumped into a non-absorbent water-tight receptacle and, after slight stirring, immediately placed in the mold.

(*b*) The test specimens shall be molded by placing the concrete in the form in layers approximately 4 in. in thickness. Each layer shall be puddled with 25 to 30 strokes with a $\frac{5}{8}$ to $\frac{3}{4}$-in. bar about 2 ft. long, tapered slightly at the lower end. After puddling the top layer, the surface concrete shall be struck off with a trowel and covered with the top cover plate which will later be used in capping the test specimens.

Capping Specimens.

6. Two to four hours after molding, the test specimens shall be capped with a thin layer of stiff neat cement paste in order that the cylinder may present a smooth end for testing. The cap can best be formed by means of a piece of plate glass $\frac{1}{4}$ in. thick and of a diameter 2 or 3 in. larger than that of the mold. This plate is worked on the fresh cement paste until it rests on top of the form. The cement for capping should be mixed to a stiff paste some time before it is to be used in order to avoid the tendency of the cap to shrink. Adhesion of the concrete to the top and bottom plates can be avoided by oiling the plates or by inserting a sheet of paraffined tissue paper.

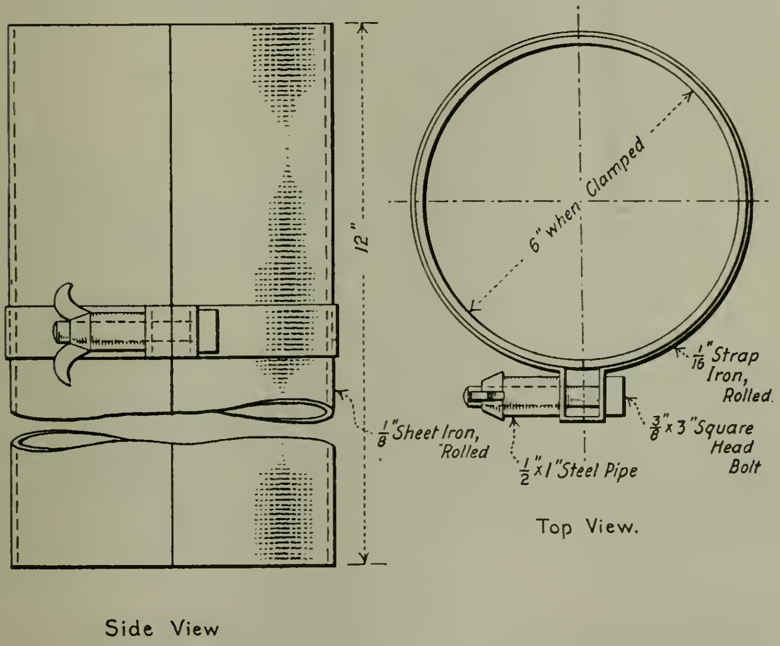


FIG. 2.

Removal of Specimens from Forms.

7. At the end of 48 hours the test specimens shall be removed from the molds and buried in damp sand except in case the molds shown in Fig. 3 are used; in this case test specimens may be buried in damp sand without removal of the mold, thus permitting shipping of the test specimens in the molds.

Storage of Specimens.

8. (*a*) The test specimens shall remain buried in damp sand until 10 days prior to the date of test. They shall then be well packed in damp sand or wet shavings and shipped to the testing laboratory, where they shall be stored either in a moist room or in damp sand until the date of test.

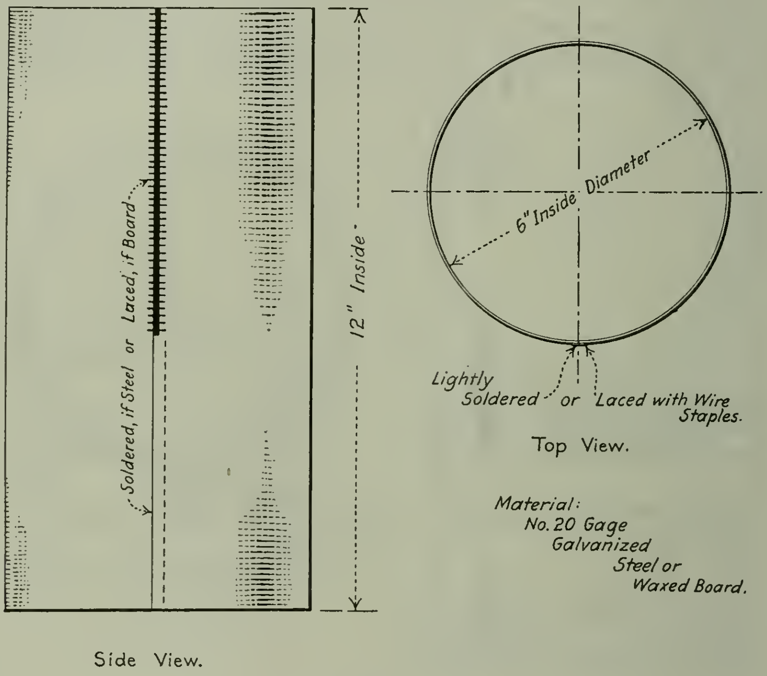

Soldered, if Steel or Laced, if Board
12" Inside
6" Inside Diameter
Lightly Soldered or Laced with Wire Staples.
Top View.
Material: No. 20 Gage Galvanized Steel or Waxed Board.
Side View.

FIG. 3.

(*b*) Should a 7-day test be required, the test specimens shall remain at the works as long as possible to harden and then shall be shipped so as to arrive at the laboratory in time to make the test on the required date.

STANDARD DEFINITIONS
OF
TERMS RELATING TO SEWER PIPE.

Serial Designation: C 8 – 15.

These definitions are issued under the fixed designation C 8; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1915.

I. FORCES ACTING UPON SEWER PIPE.

External Forces.—Forces resulting from pressures or impact acting from the outside upon the pipe.

Internal Forces.—Forces resulting from interior fluid pressure.

Abrasion.—Wearing away of surface material by friction.

II. RAW MATERIALS.

Physical Properties.—Those sensible properties of raw materials, which in their combinations affect the manufacture and use of the product.

Chemical Properties.—Those properties resulting from combinations of elements in the raw materials, which in their composition affect the manufacture and use of the product.

III. PIPE.

(*a*) *Sewer Pipe.*—Separate pipe suitable for the conveyance of domestic and industrial sewage and storm water and capable of being properly joined to form a conduit.

Clay Pipe.—Made from red burning plastic clay devoid of fissile structure. Maturing temperature about 1170° C. Vitrification not ordinarily produced, and salt glazing not always effective.

Fire-Clay Pipe.—Made from buff, gray or reddish burning fire clay showing conchoidal structure. Maturing temperature about 1250° C. Complete stony vitrification may be produced, but an absorption lower than

3 per cent is not general, nor desirable for maximum strength.

Shale Pipe.—Made from red burning hard clay with a distinct fissile structure. Vitrification at from 1050 to 1250° C., and salt glazing successful only at highest temperature.

Cement-Concrete Pipe.—Pipe formed by consolidating in a mold a mixture of Portland cement, water, sand, stone or other hard material, and permitting it to harden by natural process prior to handling and use.

Special.—A pipe other than a straight pipe.

Branch.—A pipe attached to and diverging from the barrel of another pipe, such as Y-branches, T-branches, etc.

(*b*) *Demands upon Sewer Pipes.*—Requirements of qualities which are desirable and attainable under conditions of actual practice.

IV. PARTS OF SEWER PIPE.

Barrel or Shell.—Main body of a pipe, exclusive of differently formed ends.

Ends.—Those parts of a pipe which terminate it and are so formed as to permit of making a proper joint.

Beveled End.—End surfaces of pipes inclined at an angle with the pipe axis so formed that the end of one pipe can enter the end of the adjoining pipe with a close fit.

Hub or Bell.—That end of a pipe which is sufficiently enlarged for a short distance to receive and enclose the spigot end of the adjoining pipe, to form a joint.

Spigot.—That end of a pipe which enters and is formed to fit the hub or bell of the adjoining pipe; it is sometimes scored or has a head.

Butt.—Plain end of a pipe sometimes scored on the outside, to close up against a similar end of an adjoining pipe for the purpose of forming a joint, the two ends being surrounded and covered by a collar.

Collar.—A flat band to surround and cover a butt joint.

Base, form of.—Shape of that part of a pipe which rests upon a foundation.

V. JOINTS.

Beveled.—Formed by joining pipes with beveled ends and applying the jointing material.

Hub and Spigot.—Formed by inserting the spigot end of one pipe into the hub of another and applying the jointing material.

Butt and Collar.—Formed by abutting the butt ends of two adjacent pipes and, after applying the jointing material, surrounding the joint with a collar.

Jointing Materials.—The materials which are inserted between the ends of adjoining pipes for the purpose of forming a continuous closed conduit.

Elasticity of Joints.—Ability of jointed pipes to resist strains caused by bending and returning to original position.

VI. FINISHED PRODUCT.

(*a*) *Material.*

Durability.—Resistance to disintegration or deterioration.

Serviceability.—Ability to readily and effectively render satisfactory service.

Thickness.—Distance between outside and inside surfaces.

Strength.—Ability to resist physical forces imposed during handling and after pipe has been put in use.

Toughness.—Relative degree of resistance to impact without fracture as opposed to brittleness.

Hardness.—Intensity of molecular cohesion as measured by resistance to penetration by a standard tool.

Smoothness.—Evenness of surface without projections or irregularities.

Vitrification.—The consolidation of material under high heat.

Shrinkage.—Diminution of dimensions and mass of the material.

Porosity.—Ratio of the volume of interstices of the material to the volume of its mass.

Percolation.—Passage of water through the interstices of the material.

(*b*) *Covering.*

Coating.—A covering of other materials applied in liquid form.

Glazing.—Hard glassy surface covering.

Salt Glazing.—Glazing produced by application of salt during vitrification.

Lining.—A covering of other material applied in solid form to inside surfaces.

Waterproofing.—Materials resistant to penetration by water.

(*c*) *Defects.*

Warp.—Twisted out of normal shape.

Fracture.—Rupture of the material by a break through its entire thickness.

Crack.—Fissure or open seam not necessarily extending through body of material.

Fire Crack.—A crack resulting from lack of uniformity in shrinkage after the application of excessive heat.

Hair Crack.—Irregularly running, fine, narrow crevice or fissure at the surface of a pipe not penetrating deeply, and caused by a shrinkage of material during manufacture.

Blister.—Convex hollow prominence formed by separation and raising of a film in the process of burning.

Leakage.—Passage of water contrary to intention.

Lamination.—Division of material into thin layers or sheets.

VII. IDENTIFICATION.

Marking and Imprints.—Impressions made upon pipe at the place and time of manufacture for the purpose of identification.

STANDARD DEFINITIONS
FOR
CLAY REFRACTORIES.

Serial Designation: C 27 – 20.

These definitions are issued under the fixed designation C 27; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1919; Adopted, 1920.

Method of Determining Softening Point. 1. The following definitions relating to the resistance to heat and the constancy of volume of clay refractories are recommended for the purpose of classification.

Test for Linear Contraction or Expansion. 2. The softening point referred to in the following definitions shall be determined in accordance with the Standard Method of Test for Softening Point of Fire-Clay Brick (Serial Designation: C 24) of the American Society for Testing Materials.

3. The test for linear contraction or expansion referred to in the following definitions shall be conducted in accordance with the Standard Method of Test for Porosity and Permanent Volume Changes in Refractory Materials (Serial Designation: C 20) of the American Society for Testing Materials.

I. HIGH HEAT DUTY BRICK.

(*A*) *Clay Fire Brick.*

(Silica content less than 70 per cent.)

Softening Point. 4. The softening point of clay fire brick for high heat duty shall not be lower than that of standard cone No. 31 (about 1685° C., or 3065° F.).

Linear Contraction or Expansion. 5. When duplicate samples of clay fire brick for high heat duty are heated uniformly in a suitable furnace to a temperature of 1400° C. (2552° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent of the original length nor an expansion of more than 1 per cent.

Option. 6. When a brick of this type softens at a temperature not below the softening point of standard cone No. 29 (about 1650° C., or 3002° F.) it may be tested according to classification (*B*) for silicious clay fire brick without losing in standing it if passes the tests.

(B) *Silicious Clay Fire Brick.*

(Silica content 70 per cent or over.)

Softening Point. 7. The softening point of silicious clay fire brick for high heat duty shall not be lower than that of standard cone No. 28 (about 1635° C., or 2975° F.).

Load Test. 8. All silicious clay fire brick for high heat duty shall be subjected to a load test in accordance with the requirements of the Standard Test for Refractory Materials under Load at High Temperatures (Serial Designation: C 16) of the American Society for Testing Materials. The pressure to be applied upon the brick (placed on end) shall be 25 lb. per sq. in. and the maximum furnace temperature 1350° C. (2462° F.). The brick shall not show a contraction of more than 4 per cent of the original length, nor an expansion of more than 1 per cent.

Linear Contraction or Expansion. 9. When duplicate samples of silicious clay fire brick for high heat duty are heated uniformly in a suitable furnace to a temperature of 1400° C. (2552° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent of the original length nor an expansion of more than 1 per cent.

II. INTERMEDIATE HEAT DUTY BRICK.

Softening Point. 10. The softening point of brick for intermediate heat duty shall not be lower than that of standard cone No. 28 (about 1635° C., or 2975° F.).

Linear Contraction or Expansion. 11. When duplicate samples of brick for intermediate heat duty are heated uniformly in a suitable furnace to a temperature of 1350° C. (2462° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent of the original length nor an expansion of more than 1 per cent.

III. MODERATE HEAT DUTY BRICK.

Softening Point. 12. The softening point of brick for moderate heat duty shall not be lower than that of standard cone No. 26 (about 1600° C., or 2912° F.).

Linear Contraction or Expansion. 13. When duplicate samples of brick for moderate heat duty are heated uniformly in a suitable furnace to a temperature of 1290° C. (2354° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent of the original length nor an expansion of more than 1 per cent.

IV. LOW HEAT DUTY BRICK.

14. The softening point of brick for low heat duty shall not be lower than that of standard cone No. 19 (about 1510° C., or 2750° F.). **Softening Point**

RECOMMENDED PRACTICE
FOR
LAYING SEWER PIPE.

Serial Designation: C 12 – 19.

This recommended practice is issued under the fixed designation C 12; the final number indicates the year of original adoption, or in the case of revision, the year of last revision.

Proposed as Tentative, 1915; Adopted in Amended Form, 1919.

I. PREPARING TRENCHES AND FOUNDATIONS FOR PIPE LAYING.

The foundations in the trench should be formed to prevent any subsequent settlement and thereby possibly an excessive pressure and consequent rupture of the pipes.

If the foundation is rock an equalizing bed of concrete or sand well compacted should be placed upon the rock. The thickness of these beds should be not less than 4 in. Pipes should be laid in these beds so that at least the lower third of each pipe is supported its entire length.

If the foundation is good firm earth, the earth should be pared or molded to give a full support to the lower third of each pipe and, if necessary to secure a proper bearing for the pipe, a layer of concrete, fine gravel or other suitable material should be placed. The same means of securing a firm foundation should be adopted in case the excavation has been made deeper than necessary.

If there is no good natural foundation, the pipes should be laid in a concrete cradle supported on a masonry foundation carried to a soil of satisfactory bearing power or supported on a structure designed to carry the weight of pipe and its load to a firm bearing.

Trenches should be kept free from water until the material in the joints and masonry has sufficiently hardened.

To protect pipe lines from unusual stresses all work should preferably be done in open trenches.

Pipe lines should be placed at a sufficient depth below the surface of the street to avoid dangerous pressure or impact.

When this is not possible special reinforcement should be provided.

Trenches should be only of sufficient width to provide a free working space on each side of the pipe, preferably of not over one-third of the nominal diameter, and never less than 4 in., according to the size of the pipe and the character of the ground; but in every case there should be sufficient space between the pipe and the sides of the trench to make it possible to thoroughly ram the back-filling around the pipe and to secure tight joints.

II. PIPE LAYING.

The laying of pipes in finished trenches should be commenced at the lowest point, so that the spigot ends point in the direction of flow.

All pipes should be laid with ends abutting and true to line and grade. They should be fitted and matched so that when laid in the work they will form a sewer with a smooth and uniform invert.

It is necessary to use all possible care when shoving the pipes together, so that the joints will not be unnecessarily large.

Sockets should be carefully cleaned before pipes are lowered into tenches. The pipes should be so lowered as to avoid unnecessary handling in the trench

The pipes should be set firmly according to line and grade, and the joints carefully adjusted and filled with the jointing material.

Joints should be made in the following manner: A closely twisted hemp or oakum gasket of suitable diameter, in no case less than $\frac{3}{4}$ in., and in one piece of sufficient length to pass around the pipe and lap at the top, should be solidly rammed into the annular spaces between the pipes with a suitable calking tool. When cement joints are used, the gasket should first be saturated with neat cement grout. The remainder of the space should then be completely filled with the joining materials.

III. BACKFILLING TRENCHES.

All trenches and excavations should be backfilled immediately after the pipes are laid therein, unless other protection of the pipe line is directed. The backfilling material should be selected and deposited with special reference to the future safety of the pipes. Clean earth, sand or rock dust should be solidly tamped about the pipes up to a level at least 2 ft. above the top of the pipes. This material should be carefully deposited in uniform layers. Unless otherwise permitted, each layer should be carefully and solidly tamped or rammed with proper tools so as not to injure or disturb the pipe line.

Puddling or water flooding for consolidating the backfilling is recommended only for sandy and gravely materials. If this method is used, the first flooding should be applied after the backfilling has been compacted by tamping up to 2 ft. above the top of the pipes, and the second flooding during or after the subsequent filling of the trench. An excess of water should be avoided, in order to prevent disturbance of the earth under and around the pipes and also to prevent an undue excess of pressure upon them.

Walking or working on the completed sewer, except as may be necessary in tamping or backfilling, should not be permitted until the trench has been backfilled to a height of at least 2 ft. over the top of the pipes.

The filling of the trench should be carried on simultaneously on both sides of the pipes in such a manner that injurious side pressures do not occur.

STANDARD SPECIFICATIONS

FOR

PURITY OF RAW LINSEED OIL FROM NORTH AMERICAN SEED.

Serial Designation: D 1 – 15.

These specifications are issued under the fixed designation D 1; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1915.

I. PROPERTIES AND TESTS.

Properties.

1. Raw linseed oil from North American seed shall conform to the following requirements:

	MAXIMUM.	MINIMUM
Specific Gravity at $\frac{15^\circ.5}{15^\circ.5}$ C..................	0.936	0.932
or		
Specific Gravity at $\frac{25^\circ}{25^\circ}$ C..................	0.931	0.927
Acid Number..............................	6.00	....
Saponification Number.....................	195	189
Unsaponifiable matter, per cent..............	1.50	....
Refractive Index at 25° C....................	1.4805	1.4790
Iodine Number (Hanus)....................	....	180

II. METHODS OF TESTING.

Methods of Testing.

2. The recommended methods of testing are as follows:

General.—All tests shall be made on oil which has been filtered at a temperature of between 60 and 80° F. through paper in the laboratory immediately before weighing out. The sample should be thoroughly agitated before the removal of a portion for filtration or analysis.

Specific Gravity.—Use a pyknometer, accurately standardized and having a capacity of at least 25 cc., or any other equally accurate method, making a test at 15°.5 C., water being 1 at 15°.5 C., or a test at 25° C., water being 1 at 25° C.

Acid Number.—Expressed in milligrams of KOH per gram of oil. Follow the method described in *Bulletin No. 107*, revised 1908, Department of Agriculture, Bureau of Chemistry, page 142.

Saponification Number.—Expressed as with Acid Number. Blanks should also be run to cover effect of alkali in glass. Follow method given in *Bulletin No. 107*, revised 1908, Department of Agriculture, Bureau of Chemistry, pages 137–138.

Unsaponifiable Matter.—Follow Boemer's method taken from his Ubbelohde Handbuch Der Öle u. Fette, pages 261–262. "To 100 g. of oil in a 1000 to 1500-cc. Erlenmeyer flask add 60 cc. of an aqueous solution of potassium hydroxide (200 g. KOH dissolved in water and made up to 300 cc.) and 140 cc. of 95-per cent alcohol. Connect with a reflux condenser and heat on the water bath, shaking at first until the liquid becomes clear. Then heat for one hour with occasional shaking. Transfer while yet warm to a 2000-cc. separatory funnel to which some water has been added, wash out the Erlenmeyer with water using in all 600 cc. Cool, add 800 cc. of ether and shake vigorously one minute. In a few minutes the ether solution separates perfectly clear. Draw off the soap and filter the ether (to remove last traces of soap) into a large Erlenmeyer and distill off the ether, adding if necessary one or two pieces of pumice stone. Shake the soap solution three times with 400 cc. of ether, which add to the first ether extract. To the residue left after distilling the ether add 3 cc. of the above KOH solution, and 7 cc. of the 95-per cent alcohol, and heat under reflux condenser for 10 minutes on the water bath. Transfer to a small separatory funnel, using 20 to 30 cc. of water, and after cooling shake out with two portions of 100 cc. of ether; wash the ether three times with 10 cc. of water. After drawing off the last of the water, filter the ethereal solution so as to remove the last drops of water, distill off the ether dry residue in water oven and weigh."

Or, any accurate method involving the extraction of the dried soap may be used.

Refractive Index.—Use a properly standardized Abbé Refractometer at 25° C., or any other equally accurate instrument.

Iodine Number (Hanus).—Follow the Hanus method as described in *Bulletin No. 107*, revised 1908, Department of Agriculture, Bureau of Chemistry, page 136.

STANDARD SPECIFICATIONS
FOR
PURITY OF BOILED LINSEED OIL FROM NORTH AMERICAN SEED.

Serial Designation: D 11–15.

These specifications are issued under the fixed designation D 11; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1915.

I. PROPERTIES AND TESTS.

Properties.

1. Boiled linseed oil from North American seed shall conform to the following requirements:

	Maximum.	Minimum.
Specific Gravity at $\frac{15^\circ.5}{15^\circ.5}$C.	0.945	0.937
Acid Number	8	....
Saponification Number	195	189
Unsaponifiable Matter, per cent	1.5	....
Refractive Index at 25° C.	1.484	1.479
Iodine Number (Hanus)	....	178
Ash, per cent	0.7	0.2
Manganese, per cent	....	0.03
Calcium, per cent	0.3	....
Lead. per cent	....	0.1

II. METHODS OF TESTING.

Methods of Testing.

2. The recommended methods of testing are as follows:

General.—The sample should be thoroughly agitated before the removal of a portion for analysis.

Specific Gravity.—Use a pyknometer, accurately standardized and having a capacity of at least 25 cc., or any other equally accurate method, making a test at 15°.5 C., water being 1 at 15°.5 C.

Acid Number.—Expressed in milligrams of KOH per gram of oil. Follow the method described in *Bulletin No. 107*, revised 1908, Department of Agriculture, Bureau of Chemistry, page 142.

Saponification Number.—Expressed as with Acid Number. Blanks should also be run to cover effect of alkali in glass.

Follow method given in *Bulletin No. 107*, revised 1908, Department of Agriculture, Bureau of Chemistry, pages 137–138.

Unsaponifiable Matter.—Follow Boemer's method taken from his Ubbelohde Handbuch Der Öle u. Fette, pages 261–262. "To 100 g. of oil in a 1000 to 1500-cc. Erlenmeyer flask add 60 cc. of an aqueous solution of potassium hydroxide (200 g. KOH dissolved in water and made up to 300 cc.) and 140 cc. of 95-per-cent alcohol. Connect with a reflux condenser and heat on the water bath, shaking at first until the liquid becomes clear. Then heat for one hour with occasional shaking. Transfer while yet warm to a 2000-cc. separatory funnel to which some water has been added, wash out the Erlenmeyer with water using in all 600 cc. Cool, add 800 cc. of ether and shake vigorously one minute. In a few minutes the ether solution separates perfectly clear. Draw off the soap and filter the ether (to remove last traces of soap) into a large Erlenmeyer and distill off the ether, adding if necessary one or two pieces of pumice stone. Shake the soap solution three times with 400 cc. of ether, which add to the first ether extract. To the residue left after distilling the ether add 3 cc. of the above KOH solution, and 7 cc. of the 95-per-cent alcohol, and heat under reflux condenser for 10 minutes on the water bath. Transfer to a small separatory funnel, using 20 to 30 cc. of water, and after cooling shake out with two portions of 100 cc. of ether; wash the ether three times with 10 cc. of water. After drawing off the last of the water, filter the ethereal solution so as to remove the last drops of water, distill off the ether, dry residue in water oven and weigh."

Or, any accurate method involving the extraction of the dried soap may be used.

Refractive Index.—Use a properly standardized Abbé Refractometer at 25° C., or any other equally accurate instrument.

Iodine Number (*Hanus*).—Follow the Hanus method as described in *Bulletin No. 107*, revised 1908, Department of Agriculture, Bureau of Chemistry, page 136.

Ash.—The determination of the percentage of ash and the constituents thereof may be made by any method which gives accurate results.

STANDARD SPECIFICATIONS
FOR
PURITY OF RAW TUNG OIL.

Serial Designation: D 12–16.

These specifications are issued under the fixed designation D 12; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1915; Revised, 1916.

I. PROPERTIES AND TESTS.

Properties.

1. Raw tung oil shall conform to the following requirements:

	Maximum.	Minimum.
Specific Gravity at $\frac{15^\circ.5}{15^\circ.5}$ C.	0.943	0.939
Acid Number	6	.....
Saponification Number	195	190
Unsaponifiable Matter, per cent	0.75	.....
Refractive Index at 25° C.	1.520	1.515
Iodine Number (Hübl, 18 hours)	.....	165
Heating Test (Browne's Method), minutes	12	.....
Iodine Jelly Test, minutes	4	...

II. METHODS OF TESTING.

Methods of Testing.

2. The recommended methods of testing are as follows:

Specific Gravity.—Use a pyknometer accurately standardized and having a capacity of at least 25 cc.. or any other equally accurate method, making the test at 15°.5 C., water being 1 at 15°.5 C.

Acid Number.—Weigh 10 g. of oil in a 200-cc. Erlenmeyer flask, add 50 cc. of neutral alcohol, connect with a reflux air condenser (or place small funnel in neck of flask), and heat on a steam bath for ½ hour. Remove from the bath, cool, add phenolphthalein, and titrate the free acid with N/5 sodium hydroxide. Calculate as the acid number (milligrams of potassium hydroxide to 1 g. oil).

Saponification Number.—Weigh from 2 to 3 g. of oil in a 200-cc. Erlenmeyer flask, add 30 cc. of a N/2 alcoholic solution of potassium hydroxide, connect with a reflux condenser, heat on a steam bath for 1 hour, then titrate with N/2 sulfuric acid, using phenolphthalein as indicator. Always run two blanks with the alcoholic potash. From the difference between the number of cubic centimeters of acid required by the blanks and the determinations, calculate the saponification number (milligrams of potassium hydroxide to 1 g. of oil).

Unsaponifiable Matter.—To 25 g. of oil add 15 cc. of an aqueous solution of KOH (200 g. of KOH dissolved in water and made up to 300 cc .)and 35 cc. of 95-per-cent alcohol. Connect with a reflux condenser and heat on the water bath for 1 hour with occasional shaking. Transfer to a separatory funnel containing a little water and wash out flask with water, using in all 125 cc. Cool, add 200 cc. of ether and shake vigorously for 1 minute. In a few minutes the ether solution will separate perfectly clear. Draw off the soap solution into another separatory funnel. Shake the soap solution with three 100-cc. portions of ether. Unite all the ether portions and wash with three 30-cc. portions of water. Filter the ether solution (small portions at a time) into a tared flask, distill off the ether and dry flask and contents to constant weight at 95 to 100° C. in a steam oven. Report the percentage of unsaponifiable matter.

Refractive Index.—Use a properly standardized AbLé refractometer at 25° C., or any other equally accurate instrument.

Iodine Number (Hübl).—Place a small quantity of oil into a small weighing bottle or beaker. Weigh carefully. Transfer by dropping from 0.2 to 0.3 g. to a 500-cc. bottle having a well-ground stopper, or a specially flanged neck, iodine-test Erlenmeyer flask. Reweigh the weighing bottle or beaker to determine the amount of oil used in the test. Then dissolve the oil in 10 cc. of chloroform and add an amount of Hübl solution containing twice the amount of iodine that will be absorbed by the oil. Stopper the flask, shake well, and place in a dark closet for 18 hours. Add 20 cc. of a 10-per-cent solution of potassium iodide and 100 cc. of distilled water. Titrate with N/10 sodium thiosulfate, using starch as an indicator. Blank tests must be made. From the difference between the amounts of sodium thiosulfate required by the blanks and the determination, calculate the iodine number (centigrams of iodine to 1 g. of oil).

On account of the fact that Hübl solution after preparation is apt to deteriorate in strength, it is considered advisable to have prepared the two component parts of Hübl solution, namely, a solution of mercuric chloride in alcohol and a solution of iodine in alcohol, of the proper strength, as outlined in text-books. The proper amounts of these solutions may be mixed on the day of use.

Heating Test (Browne's Method).—Test tubes for containing the oil should be 16 cm. by 15 mm., with a mark near the bottom to indicate 5 cc., and closed by a cork so perforated that a glass rod 3 mm. in diameter could move freely.

Fill a copper beaker (height, 12 cm.; internal diameter, 6 cm.) with cotton-seed oil to a height of 7.5 cm. Place a thermometer so as to be 1.5 cm. from the bottom of the bath.

Use a nitrogen-filled, immersed-stem chemical thermometer, engraved stem; total length 4 to 4½ in.; graduated from 210 to 310° C. in 2° intervals; the length between 210 and 310° C. not less than 2½ in. If preferred, use emergent-stem thermometer 30 cm. long, with graduations from 100 to 400° C., making correction for emergent stem according to the method outlined in Stem Correction Sheet No. 44 of the U. S. Bureau of Standards.

When the bath temperature is 293° C. (560° F.) and very slowly rising at this point, place the tube containing 5 cc. of the oil to be tested so that its bottom is level with the lowest part of the bulb of the thermometer. Note the time, remove the source of heat for about 45 seconds and then reapply. Before 2 minutes have elapsed the temperature of the bath will have fallen to 282° C. (540° F.), at which point it should be kept as steady as possible. When the tung oil has been in the bath about 9 minutes, raise the glass rod at intervals of ½ minute, and when the rod is firmly set note the time. As setting or jellying takes place within a few seconds of fluidity, a good end determination is afforded. Remove the specimen at once, heat the bath again to 293° C., and repeat the experiment with another portion of the sample.

No stirrer is used in the bath. A screen around the bath enables the temperature to be more easily reached. When the cotton-seed oil has become tarry and viscid, it should be renewed; otherwise heating may be irregular.

Iodine Jelly Test.—In a wide-necked 200-cc. Erlenmeyer flask, place 2.5 g. (weight correct to 1 mg.) of the oil. Add 10 cc. of chloroform from a pipette and stopper the flask immediately. Carefully insert a small glass vial into the flask so that the vial stands upright. Into the vial from a pipette run 10 cc. of a solution of iodine in chloroform, containing 0.035 to 0.036 g. of iodine per cubic centimeter. Place the flask in a bath containing water at 25 to 26° C. and allow it to stand there for a few minutes. Keep the flask stoppered, except when it is necessary to remove it to insert the vial and to add the iodine solution. Tilt and rotate the flask so that the vial is upset and the contents of the flask are thoroughly mixed, at the same time starting a stop watch. Keep the flask in the bath at 25 to 26° C. and at the end of every quarter minute, tilt the flask towards a horizontal position. Note the time required for the formation of a jelly that does not flow, but sticks to the bottom of the flask or slides as a mass. Record time in minutes and quarters thereof. Pure tung oil should require $2\frac{3}{4}$ to $3\frac{1}{4}$ minutes for the formation of the jelly. If the temperature of the laboratory is more than 2 or 3° C. above or below 25° C., place the flask containing the iodine solution in the bath and allow it to remain there for several minutes before pipetting out the 10 cc. for the test. The arrangement of the apparatus is shown in Fig. 1. The chloroform used to dissolve the oil and to prepare the iodine solution shall conform to the requirements of the United States Pharmacopœia and shall have a specific gravity at 25°/25° C. of not more than 1.481 and not less than 1.480. The proper density can be obtained by washing with water if the specific gravity is too low or by adding 95-per-cent ethyl alcohol if too high.

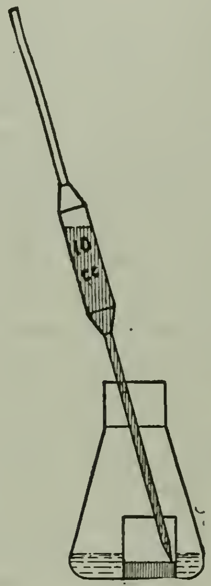


FIG. 1.

A convenient procedure for preparing the iodine solution is as follows: Treat an excess of iodine with warm chloroform and after shaking for a few minutes, cool the contents to about 20° C. and filter through glass wool. Pipette 10 cc. of the solution into a flask containing 10 cc. of 10-per-cent potassium-iodide solution and titrate with 0.1 normal sodium-thiosulfate solution. Calculate the iodine content and dilute with chloroform so as to obtain an iodine content of 0.035 to 0.036 g. per cc. After dilution, titrate again against the thiosulfate to be sure that the solution is of required strength.

All the details of the above method shall be followed exactly.

STANDARD METHODS OF TESTING SHELLAC.

Serial Designation: D 29 – 17.

These methods are issued under the fixed designation D 29; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PPOPOSED AS TENTATIVE, 1914; ADOPTED, 1917.

DETERMINATION OF ROSIN.

Solutions Required.—The solutions required are one of iodine monochloride containing 13 g. of iodine per liter, in glacial acetic acid that has a melting point of 14.7 to 15° C. and is free from reducing impurities; and another of sodium thiosulfate, made by dissolving 24.83 g. of the pure salt in a liter of water. In addition to these solutions there is required a quantity of acetic acid of the same strength as that used for making the solution of iodine monochloride. Pure chloroform and starch are also necessary.

The preparation of the iodine-monochloride solution presents no great difficulty, but it shall be done with care and accuracy in order to obtain satisfactory results. There shall be in the solution no sensible excess either of iodine or more particularly of chlorine, over that required to form the monochloride. This condition is most satisfactorily attained by dissolving in the whole of the acetic acid to be used the requisite quantity of iodine, using a gentle heat to assist the solution, if it is found necessary. Set aside a small portion of this solution, while pure, and pass dry chlorine into the remainder until the halogen content of the whole solution is doubled. Ordinarily it will be found that by passing the chlorine into the main part of the solution until the characteristic color of free iodine has just been discharged, there will be a slight excess of chlorine, which is corrected by the addition of the requisite amount of the unchlorinated portion until all free chlorine has been destroyed. A slight excess of iodine does little or no harm, but excess of chlorine must be avoided.

Method.—Introduce 0.2 g. of ground shellac into a 250-cc.

dry bottle of clear glass with a ground-glass stopper, add 20 cc. of glacial acetic acid (melting point 14.7 to 15° C.) and warm the mixture gently until solution is complete (except for the wax). A pure shellac is rather difficultly soluble; solution is quicker according to the proportion of rosin present. Add 10 cc. of chloroform and cool the solution to 21 to 24° C. The temperature should be held well within these limits during the test. Add 20 cc. of Wijs solution from a pipette, having a rather small delivery aperture. Close the bottle, place in a dark place, and note the time. It is convenient to keep the bottles during the test partly immersed in water which should be kept as nearly as possible between 22 and 23° C.

Pure shellac will scarcely alter the color of the Wijs solution. If in small amount, rosin will produce a slowly appearing red-brown color. In large amount, rosin causes an immediate coloration, increasing in intensity as time passes. After 1 hour, add 10 cc. of 10-per-cent potassium-iodide water solution. Titrate the solution immediately with the sodium-thiosulfate solution; 25 or 30 cc. may be run in immediately, unless the shellac is very impure, and the remainder gradually, with vigorous shaking. Just before the end, add a little starch solution. The end point is sharp, as the reaction products of shellac remain dissolved in the chloroform; any color returning after ½ minute or so is disregarded.

A blank determination should be run with 20 cc. of Wijs solution, 20 cc. of acetic acid, 10 cc. of chloroform, and 10 cc. of 10-per-cent potassium-iodide solution. The blank is necessary on account of the well-known effect of temperature changes on the volume, and possible loss of strength of the Wijs solution.

In the case of grossly adulterated samples, or in the testing of pure rosin, it is necessary to use, instead of 0.2 g. of material, a smaller amount, say 0.15 g. or even 0.1 g., in order that the excess of iodine monochloride may not be too greatly reduced, since the excess of halogen is one of the factors in determining the amount of absorption. In case less than 25 cc. of the thiosulfate solution are required, another test should be made, using a smaller amount of the shellac to be tested.

In weighing shellac, some difficulty is at times experienced on account of its electrical properties. In very dry weather it may be found that the necessary handling to prepare it for weighing has electrified it, and that it may be necessary to leave it on the balance pan at rest for a few minutes before taking the final weight.

No pure shellacs show a higher iodine absorption than 18. As shellac is relatively a high-priced material and as the variation between its highest and lowest figure is not great, it is recommended that 18 should be taken as the standard figure for shellac, determined by the method above described.

As it is an accepted principle that a standard method should be so devised that its inaccuracies shall work in the direction of favoring the seller rather than of condemning too severely the article sold, it is recommended that the value for the iodine number of rosin be taken as 228. The results of using in this method the value 18 as the iodine number of shellac and 228 as the number of rosin, may be that a slightly lower percentage of rosin, under some circumstances, will be found than that which is actually present.

The percentage of rosin is determined as follows:

Iodine number of shellac = 18
" " " rosin = 228
" " " mixture = X

$$\text{Percentage of rosin} = 100\,\frac{(X-18)}{(228-18)}$$

ALCOHOL-INSOLUBLE MATTER.[1]

The separation of the soluble from the insoluble portion of the lac is made by extracting approximately 5 g. of the lac in a paper cartridge, which is held in a tube provided with a siphon as in the Knoefler extraction apparatus, and is heated by the vapors of the alcohol which pass around the tube and are then condensed by a return condenser to fall as liquid upon the shellac to be extracted. The siphon tube should be slightly larger than the cartridge, which should be supported so that it does not rest directly on the bottom.

The most convenient apparatus for carrying out the process is illustrated in Fig. 1. It consists of a wide-neck flask in which is suspended a metal return condenser. From the lower part of this condenser is hung a siphon tube of the Knoefler type. A Schleicher and Schuell extraction cartridge, No. 603, 26 mm. in diameter by 60 mm. high, is used in a siphon tube of such a size that the top of the cartridge is just above the upper curve of the siphon, the paper thimble being cut down if necessary. It is supported on three indentations in the glass so that there is a little space underneath and around the cartridge to allow of a free flow of liquid. To insure the complete extraction of all matters soluble in alcohol in the cartridge itself, it should be thoroughly extracted with 99.5-per-cent methyl alcohol before use. Then place the cartridge in a glass-stoppered weighing bottle and dry to constant weight in an air bath at 100° C. Place a sample of approximately 5 g. of the pulverized lac in the cartridge, and transfer to the extraction apparatus. Fill the cartridge with cold alcohol of the character described to a point just below the upper curve in the siphon. The cold alcohol is allowed to act upon the lac for 1 hour before the extraction commences.

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[1] Sometimes referred to as "refraction" of the lac.

Keep the alcohol boiling briskly during the extraction. The rate of extraction may be controlled by the use of an electric stove of the Simplex type, 4½ in. in diameter, and using the full current of 2.2 amperes at 110 volts. The volume of methyl alcohol in the flask should be 125 cc., in addition to the alcohol required to fill the siphon. Protect the flask from drafts. Under these conditions the tube will siphon over about 33 times in 1 hour. The condenser should be able to return all the alcohol volatilized during the vigorous boiling of the contents of the flask, the object being to effect the maximum extraction during the specified time.

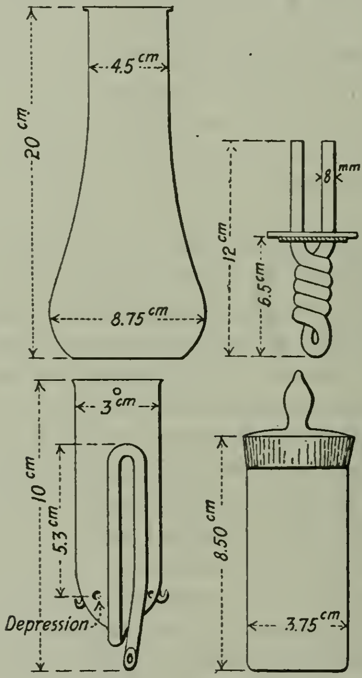

FIG. 1.—Apparatus for Test for Alcohol-Insoluble Matter.

The color is removed by the end of the first hour in practically every case and in order to eliminate any variations due to difference of opinion as to the exact time when the color has disappeared, the total extraction period shall be limited to exactly 2 hours, time being taken from the moment when the first siphon tube of alcohol has passed over. After extraction, place the cartridge in the weighing bottle, dry to constant weight at 100° C. and weigh.

The weight of the residue insoluble in alcohol thus obtained, divided by the weight of the sample, and this quotient multiplied by 100, is the percentage of alcohol-insoluble matter in the lac.

NOTE.

It will be noted that there are three depressions in the lower part of the glass extraction thimble to hold the cartridge above the bottom. This is very necessary for the reason that during the early part of the extraction, a very free flow must be maintained to prevent the blocking of the siphon with the wax, which, though readily soluble in hot alcohol, is with difficulty soluble in cold alcohol. The object in filling the cartridge with cold alcohol, before starting the extraction proper, is to allow the resin and some of the wax to dissolve at a low temperature. If the higher temperature of the boiling alcohol were immediately applied it would fuse the resin into a lump and render the extraction difficult. The first few drops of distilled alcohol which fall into the cartridge will cause the extract to siphon over, thus eliminating the bulk of the resin at the start.

DETERMINATION OF MOISTURE IN BLEACHED SHELLAC.

Both orange and bleached shellac give off volatile matter at temperatures approaching 100° C. Bleached shellac alters chemically at these temperatures, losing its solubility in alcohol. For these reasons the usual methods of determining moisture by heating in the air bath at 100 to 110° C. are not applicable in the analysis of shellac.

Sampling.—Bleached shellac is sold in three forms, as hanks or bars containing approximately 25 per cent of water, as ground bleached in pulverized form with about the same water content, and as bone-dry or kiln-dried shellac. The latter is prepared by drying the ground-bleached shellac in the air or in vacuum driers at moderate temperatures. It may contain, depending upon the completeness of the drying and weather conditions, up to 10 per cent or more of water.

In sampling bone-dry or kiln-dried bleached shellac, a fairly large portion (about 1 lb.) should be taken from different parts of the barrel and finely ground by running quickly through a coffee mill. No attempt shall be made to sieve it. It shall be rapidly mixed and transferred to a Mason jar provided with a screw cap and rubber ring seal. The jar should not be more than two-thirds full, leaving room for a thorough mixing by shaking the contents. It shall be kept in a cool place and tested as promptly as possible. If too warm the shellac may become partly caked, in which case the lumps shall be broken up by shaking the bottle.

In sampling bars or hanks it is recommended that a whole hank be taken. It should be crushed and ground as rapidly as possible. Ground-bleached shellac may be treated as above, bearing in mind that the large amount of moisture present makes rapid handling imperative.

Method No. 1.—Weigh from 5 to 10 g. of the sample in flat-bottom dishes about 4 in. in diameter or in watch glasses ground to fit and provided with a clamp. Spread out the contents of the dish in a thin layer to expose as large a surface as possible. Place the shellac in a desiccator freshly filled with concentrated sulfuric acid. Exhaust the desiccator by a vacuum pump as completely as possible. With a good vacuum (3 mm. pressure or better) constant weight will be obtained in between 24 and 48 hours.

Absolutely dry shellac is quite hygroscopic and the final weight should be taken as rapidly as possible.

Method No. 2.—The same results may be obtained by drying the shellac in a well-ventilated air bath from 3 to 6 hours at 100 to 110° F. (38 to 43° C.). One or two electric light bulbs provide a convenient source of heat. The temperature should not be allowed to rise above 43° C., otherwise sintering may occur and retard drying. With poorly ventilated ovens the drying may take much longer. Completeness of drying should be ascertained by continuing the treatment to constant weight.

It is recommended that analysts check the accuracy of results obtained in the oven by comparison with a test made in a vacuum desiccator before relying exclusively on the oven.

NOTE.

When the determination of alcohol insoluble matter in bleached shellac is required. the sample shall be dried if in the form of bars or ground bleached, as the water present dilutes the alcohol to a point where solution may not be complete. Prolonged heating at the temperatures of 38 to 43° C. stated above may render the shellac partly insoluble, and it is recommended that in preparing shellac for this determination a separate portion be dried by exposure to the air in a thin layer, without the application of heat.

STANDARD METHOD OF TEST
FOR
FLASH POINT OF VOLATILE FLAMMABLE LIQUIDS.

Serial Designation: D 56 – 21.

This method is issued under the fixed designation D 56; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1918; Adopted in Amended Form, 1919;
Revised, 1921.

Tester to be Used.

1. (*a*) The Tag Closed Tester shall be used for all volatile flammable liquids flashing below 175° F. with the exception of products classed as Fuel Oil. Determination of the flash point of fuel oil by the Tag Tester is permissible, but the Pensky-Martens Tester is to be preferred.

Dimensions of Tester.

(*b*) The Tag Closed Tester shall conform to the following dimensions within the limits of tolerances given:

Dimension.	Normal.	Tolerances
Depth of water surface below top of cup, in.	$1\frac{3}{32}$ (27.8 mm.)	$\pm\frac{1}{64}$ (0.4 mm.)
Depth of oil surface below top of cup, in.	$1\frac{3}{32}$ (29.4 mm.)	$\pm\frac{1}{64}$ (0.4 mm.)
Depth of top of bulb of oil thermometer when in place below top of cup, in.	$1\frac{5}{16}$ (33.3 mm.)	$\pm\frac{1}{32}$ (0.8 mm.)
Inside diameter of oil cup at top, in.	$2\frac{1}{8}$ (54.0 mm.)	±0.005 (0.1 mm.)
Weight of oil cup, g.	68	±1
Diameter of bead on top of cover, in.	$\frac{5}{32}$ (4.0 mm.)	$\pm\frac{1}{64}$ (0.4 mm.)

The plane of underside of cover to be between the top and bottom of the burner tip when the latter is fully depressed.

Specifications for Thermometer.

(*c*) The Thermometer shall conform to the following specifications:

Type: Etched stem glass.

Total length: 275 mm.

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 6 to 7 mm.

Bulb: Corning Normal, Jena 16 III or equally suitable thermometric glass. Diameter less than stem, length 9 to 13 mm.

Actuating liquid: Mercury.

Range: 20° F. to 230° F.

Immersion: $2\frac{1}{4}$ in. (57 mm.) from end of bulb. Words "$2\frac{1}{4}$-in. immersion" etched on the stem, also a line around the stem to indicate depth of immersion.

Distance to 20° line from bottom of bulb: 75 to 90 mm.

Distance to 230° line from top of stem: 25 to 40 mm.

Expansion chamber: Required.

Graduation: All lines, figures and letters clear cut and distinct. Scale graduated in 1° divisions. Scale numbered every 10°, the first and each succeeding 5° line to be longer than the others.

Special marking:[1] "A.S.T.M. P.M. and Tag," serial number, manufacturer's name or trade mark etched on the stem.

Accuracy: Error at any point in scale shall not exceed 1° F.

Points to be tested: 32°, 100°, 150°, 212° F.

General Directions.

2. (*a*) If gas is available, connect a $\frac{1}{8}$-in. rubber tube to the corrugated gas connection on the oil cup cover. If no gas is available, unscrew the test flame burner-tip from the oil chamber on the cover, and insert a wick of cotton cord in the burner-tip and replace it. Put a small quantity of cotton waste in the oil chamber, and insert a small quantity of signal, sperm or lard oil in the chamber, light the wick and adjust the flame, so that it is exactly the size of the small white bead mounted on the top of the tester.

(*b*) The test shall be performed in a dim light so as to see the flash plainly.

(*c*) Surround the tester on three sides with an inclosure to keep away draughts.

A shield about 18 in. square and 2 ft. high, open in front, is satisfactory, but any safe precaution against all possible room draughts is acceptable. Tests made in a laboratory hood or near ventilators will give unreliable results.

(*d*) See that the tester sets firm and level.

(*e*) For accuracy, the flash-point thermometers which are especially designed for the instrument should be used, as the position of the bulb of the thermometer in the oil cup is essential.

Water Bath.

3. Put the water-bath thermometer in place, and place a receptacle under the overflow spout to catch the overflow. Fill the water bath with water at such a temperature that, when testing is started, the temperature of the water bath will be at least 20° F. (11° C.) below the probable flash point of the oil to be tested.

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[1] This thermometer is identical with the low range instrument specified for use with the A.S.T.M. Pensky-Martens Closed Tester.

Oil Cup. 4. Put the oil cup in place in the water bath. Measure 50 cc. of the oil to be tested in a pipette or a graduate, and place in the oil cup. The temperature of the oil shall be at least 20° F. (11° C.) below its probable flash point when testing is started. Destroy any bubbles on the surface of the oil. Put on the cover, with flash-point thermometer in place and gas tube attached. Light the pilot light on the cover and adjust the flame to the size of the small white bead on the cover.

Heating. 5. Light and place the heating lamp, filled with alcohol, in the base of the tester and see that it is centrally located. Adjust the flame of the alcohol lamp so that the temperature of the oil in the cup rises at the rate of about 1°.8 F. (1° C.) per minute, not faster than 2° F. (1°.1 C.) nor slower than 1°.6 F. (0°.9 C.) per minute.

Testing. 6. (*a*) Record the barometric pressure which, in the absence of a laboratory instrument, may be obtained from the nearest Weather Bureau Station.

(*b*) Record the temperature of the oil sample at start.

(*c*) When the temperature of the oil reaches 9° F. (5° C.) below the probable flash point of the oil, turn the knob on the cover so as to introduce the test flame into the cup, and turn it *promptly* back again. Do not let it snap back. *The time consumed in turning the knob down and back should be about one full second*, or the time required to pronounce distinctly the words "one-thousand-and-one."

(*d*) Record the time of making the first introduction of the test flame.

(*e*) Record the temperature of the oil sample at the time of first test.

(*f*) Repeat the application of the test flame at every 1° F. (0°.5 C.) rise in temperature of the oil until there is a flash of the oil within the cup.

Do not be misled by an enlargement of the test flame or halo around it when entered into the cup, or by slight flickering of the flame; the true flash consumes the gas in the top of the cup and causes a very slight explosion.

(*g*) Record the time at which the flash point is reached.

(*h*) Record the flash point.

(*i*) If the rise in temperature of the oil, from the "time of making the first introduction of the test flame" to the "time at which the flash point is reached" was faster than 2° F. (1°.1 C.) or slower than 1°.6 F. (0°.9 C.) per minute, the test should be questioned, and the alcohol heating lamp adjusted so as to correct the rate of heating. It will be found that the wick of this lamp can be so accurately adjusted as to give a uniform rate of rise in temperature within the above limits and remain so.

Repeat Tests

7. (*a*) It is not necessary to turn off the test flame with the small regulating valve on the cover; leave it adjusted to give the proper size of flame.

(*b*) Having completed the preliminary test, remove the heating lamp, lift up the oil cup cover, and wipe off the thermometer bulb. Lift out the oil cup, and empty and carefully wipe it. Throw away all oil samples after once used in making a test.

(*c*) Pour cold water into the water bath, allowing it to overflow into a receptacle, until the temperature of the water in the bath is lowered to 15° F. (8° C.) below the flash point of the oil, as shown by the previous test.

With cold water of nearly constant temperature, it will be found that a uniform amount will be required to reduce the temperature of the water bath to the required point.

(*d*) Place the oil cup back in the bath and measure into it a 50-cc. charge of fresh oil. Destroy any bubbles on the surface of the oil, put on the cover with its thermometer, put in the heating lamp, record the temperature of the oil, and proceed to repeat the test as described above in Sections 4 to 6, inclusive. Introduce the test flame for first time at a temperature of 10° F. (5°.5 C.) below the flash point obtained on the previous test.

Average Value of Flash Point.

8. If two or more determinations agree within 1° F. (0°.5 C.), the average of these results, corrected for barometric pressure, shall be considered the flash point. If two determinations do not check within 1° F. (0°.5 C.), a third determination shall be made and, if the maximum variation of the three tests is not greater than 2° F. (1° C.), their average, after correcting for barometric pressure, shall be considered the flash point.

Correction for Barometric Pressure.

9. Correction for barometric pressure shall only be made in cases of dispute or when the barometer reading varies more than ½ in. (13 mm.) from the standard pressure of 29.92 in. (760 mm.). When the barometer reading is below this standard pressure, add to the thermometer reading 1°.6 F. (0°.9 C.) for each inch (25 mm.) of barometer difference to obtain the true flash point. When the barometer reading is above the standard pressure, deduct 1°.6 F. (0°.9 C.) for each inch (25 mm.) of barometer difference to obtain the true flash point.

STANDARD METHODS OF ROUTINE ANALYSIS
OF
WHITE PIGMENTS.

Serial Designation: D 34 – 17.

These methods are issued under the fixed designation D 34; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1915; Adopted, 1917.

I. METHOD FOR VERY SMALL AMOUNTS OF IRON.

Lead Pigments.—Treat sample with HNO_3 (1 : 1) in usual manner, dilute with H_2O, add H_2SO_4 to precipitate bulk of lead (not necessary to evaporate down); cool, filter, wash with 1 to 2 per cent of H_2SO_4, make filtrate just alkaline with NH_4OH, then just acid with dilute HNO_3, determine iron colorimetrically by the thiocyanate method, using same amounts of reagents in preparing standards. If sample contains insoluble matter, filter out and wash with hot water till Pb-free, and to filtrate add H_2SO_4 and proceed as given. The insoluble is ignited, treated with HF and H_2SO_4 in usual manner, brought into solution (filter out any $BaSO_4$), and added to filtrate from $PbSO_4$. If necessary, solution may be made up to volume and aliquots taken. Copper, if present, shall be removed by precipitating the Fe with NH_4OH, filtering, washing, redissolving $Fe(OH)_3$ and proceeding as above.

Other Pigments.—Treat as above, omitting the addition of H_2SO_4.

II. GENERAL METHOD.

True specific gravity shall be determined by Thompson's[1] method, or by means of a 50-cc. pyknometer, using c. p. benzene and 10 to 20 g. of pigment.

Basic Carbonate of Lead.

Total Lead (Gravimetric).—Dissolve 1 g. in 20 cc. of HNO_3 (1:1) in a covered beaker, heating till all CO_2 is expelled;

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XIII, p. 407 (1913).

wash off cover, add 20 cc. of H_2SO_4 (1:1) and evaporate to fumes of SO_3, cool, add about 150 cc. of water and 150 cc. of ethyl alcohol; let stand in *cold* water 1 hour, filter on a Gooch crucible, wash with 95-per-cent ethyl alcohol, dry at 110° C., and weigh $PbSO_4$; calculate to PbO or to basic carbonate.[1] Instead of determining the lead as sulfate, the sample may be dissolved by boiling with acetic acid; then dilute to about 200 cc. with water, make alkaline with NH_4OH, then acid with acetic acid, heat to boiling and add 10 to 15 cc. of a 10-per-cent solution of potassium dichromate; heat till the yellow precipitate assumes an orange color. Let settle and filter on a Gooch crucible, washing by decantation with hot water till the washings are colorless finally transferring all of the precipitate. Then wash with 95-per-cent ethyl alcohol and then ether; dry at 110° C. and weigh $PbCrO_4$. (Any insoluble matter should be filtered out before precipitating the lead.)

Total Lead (Volumetric).—Dissolve 0.5 g. of sample in 10 cc. of concentrated hydrochloric acid, boil till solution is effected, cool, dilute to 40 cc., neutralize with ammonium hydroxide. Add acetic acid until distinctly acid, dilute to 200 cc. with hot water, boil and titrate with ammonium molybdate as follows:

Dissolve 4.25 g. of ammonium molybdate in water and make up to one liter. To standardize this solution, dissolve about 0.2 g. of pure lead foil in nitric acid (pure PbO or $PbSO_4$ may also be used), evaporate nearly to dryness, add 30 cc. of water, then 5 cc. H_2SO_4 (sp. gr. 1.84), cool, and filter. Drop filter with $PbSO_4$ into a flask, add 10 cc. of concentrated HCl, boil till completely disintegrated, add 15 cc. of HCl, 25 cc. of water, and NH_4OH till alkaline. Acidify with acetic acid, dilute to 200 cc. with hot water and boil. Titrate, using an outside indicator of one part of tannic acid in 300 parts of water.

It should be noted that when calcium is present, it forms a more or less insoluble molybdate, and results are apt to be high. With samples containing less than 10 per cent of lead, the lead should be precipitated as $PbSO_4$, filtered, redissolved and titrated as in the process of standardizing.

Carbon Dioxide.—Determine by evolution with dilute hydrochloric acid absorbing in soda-lime or KOH solution. Calculate CO_2 to $PbCO_3$, subtract PbO equivalent from total PbO and calculate residual PbO to $Pb(OH)_2$.

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[1] This method of weighing lead sulfate is not accurate in the presence of calcium compounds.

Acetic Acid.[1]—Place 18 g. of the pigment in a 500-cc. flask, add 40 cc. of sirupy phosphoric acid, 18 g. of zinc dust and 50 cc. of water. Connect to a straight Liebig condenser, apply heat and distill down to a small bulk. Then pass steam into the flask until it becomes about half full of condensed water, shut off the steam and distill down to a small bulk—this operation being conducted twice. To the total distillate which was collected in a larger flask add 1 cc. of sirupy phosphoric acid, connect to a Liebig condenser, using a spray trap, and distill to a small volume—about 20 cc. Pass steam through till about 200 cc. of water condense in the distillation flask, shut off steam and continue the distillation. These operations of direct and steam distillations are conducted until 10 cc. of the distillate require only one drop of 0.1 N alkali to give a change in the presence of phenolphthalein. Then titrate the total distillate with 0.1 N sodium hydroxide and phenolphthalein and calculate the total acidity as acetic acid. It will be found convenient to titrate each 200-cc. portion of the distillate as collected.

Metallic Lead.[1]—Weigh 50 g. of the sample into a 400-cc. beaker, add a little water and add slowly 60 cc. of 40-per-cent acetic acid and after effervescence has ceased, boil on hot plate. Fill the beaker with water, let settle, and decant the clear solution. To the residue add 100 cc. of a mixture of 360 cc. of strong NH_4OH, 1080 cc. of water, 2160 cc. of 80-per-cent acetic acid and boil until all solution is complete. Fill beaker with water, let settle and decant the clear solution. Collect residue on a watch glass, floating off everything but metallic lead. Dry and weigh. Result × 2= percentage of metallic lead in sample.

The following method of A. N. Finn (unpublished) gives total basicity of a pure white lead: Place 2 g. of pigment in an evolution flask, add a little CO_2-free water, connect up to the separatory funnel and condenser (Knorr type), add through the funnel, finally washing down, 100 cc. of N/4 nitric acid, boil and absorb the CO_2 in soda-lime tube in usual manner (having H_2SO_4 and $CaCl_2$ drying tubes in train) and weigh. To the solution in the evolution flask, add about 20 cc. of neutral sodium-sulfate solution and titrate with N/4 sodium-hydroxide solution (carbonate-free), using phenolphthalein. CO_2 is calculated to $PbCO_3$. The amount of N/4 acid corresponding to the CO_2 is calculated and deducted from the total amount of N/4 acid neutralized by the sample and the difference calculated to combined H_2O, from which $Pb(OH)_2$ is computed.

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[1] Thompson's Method, *Journal*, Soc. Chem. Ind., Vol. 24, p. 487 (1905)

BASIC SULFATE OF LEAD.[1]

Determination of Total Lead.—Dissolve 1 g. of the sample in 100 cc. of a mixture consisting of 125 cc. of 80-per-cent acetic acid, 95 cc. of NH_4OH (sp. gr. 0.90) and 100 cc. of water. Add the solution while hot and dilute with about 50 cc. of water, boil until sample is dissolved. Dilute to 200 cc. and titrate with standard ammonium-molybdate solution as described under basic carbonate of lead. The ammonium-molybdate solution contains about 8.67 g. per liter and is standardized against pure lead foil, pure PbO or pure $PbSO_4$.

Determination of Total Zinc.—Boil 1 g. of the sample with 30cc. of water, 4 g. of NH_4Cl and 6 cc. of concentrated HCl (some $PbSO_4$ or $PbCl_2$ may not dissolve). Dilute to 200 cc. with hot water, add 2 cc. of a saturated solution of sodium thiosulfate and titrate with a standard solution of potassium ferrocyanide in usual manner. Calculate the zinc to ZnO,[2] as follows:

99.70[a] − percentage of ZnO found = percentage of lead constituents;

then

$$\frac{\left(\frac{\text{Molecular weight PbSO}_4}{\text{Atomic weight Pb}}\times\begin{matrix}\text{Percentage of}\\ \text{Pb found}\end{matrix}\right)-\begin{matrix}\text{Percentage of}\\ \text{Pb constituents}\end{matrix}}{\frac{\text{Molecular weight PbSO}_4-\text{Molecular weight PbO}}{\text{Molecular weight PbO}}}=\begin{matrix}\text{percent-}\\ \text{age of}\\ \text{PbO}\\ \text{present.}\end{matrix}$$

$$\frac{\left(\frac{\text{Molecular weight PbO}}{\text{Atomic weight Pb}}\times\begin{matrix}\text{Percentage of}\\ \text{Pb found}\end{matrix}\right)-\begin{matrix}\text{Percentage of}\\ \text{Pb constituents}\end{matrix}}{\frac{\text{Molecular weight PbO}-\text{Molecular weight PbSO}_4}{\text{Molecular weight PbSO}_4}}=\begin{matrix}\text{percentage}\\ \text{of PbSO}_4\\ \text{present.}\end{matrix}$$

Sulfur Dioxide.—Digest 2 g. of the sample with frequent stirring in 100 cc. of freshly boiled *cold* water and 5 cc. of concentrated HCl; let stand 10 to 15 minutes, add an excess of 0.01-normal iodine solution and titrate back with 0.01-normal sodium-thiosulphate solution, using starch indicator. Report as SO_2. Run blank on reagents and make corrections. Or, the SO_2 may be titrated directly with iodine.

Soluble Zinc Sulfate.—Determine as under "Zinc-Lead and Leaded Zincs."

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[1] J. A. Schaeffer's Method, *Journal of Industrial and Engineering Chemistry*, Vol. 6, p. 200 (1914), may be used.

[2] It would probably be more accurate to remove total lead as $PbSO_4$ and titrate the zinc in the filtrate after adding NH_4OH and HCl in usual manner.

[a] This figure (99.70) is the average total percentage of $PbSO_4$, PbO and ZnO, found in 270 total analyses of basic lead sulfate.

ZINC-LEAD AND LEADED-ZINCS (OZLO WHITE).

Total Lead and Zinc.—Dissolve 1 g. of the sample by boiling with 250 cc. of water and 20 cc. of concentrated HNO_3, add 5 cc. of concentrated H_2SO_4, and evaporate to copious fumes of SO_3; cool, add 250 cc. of water, let stand *cold* 1 to 2 hours, filter on Gooch crucible, wash with 1-per-cent H_2SO_4, ignite, and weigh as $PbSO_4$. Report as $PbSO_4$. The $PbSO_4$ may be filtered on paper and then dissolved and titrated with ammonium-molybdate solution as described under basic carbonate of lead. Make filtrate from $PbSO_4$ alkaline with NH_4OH, then acid with HCl, add 3 cc. of concentrated HCl, heat to nearly boiling, and titrate the total zinc with potassium-ferrocyanide solution using uranium-acetate solution as an outside indicator and calculate to ZnO. (Iron, copper, or other interfering substances should first be removed as described by Low.)

Sulfates other than Barium Sulfate.—Treat 0.5 g. of the sample with 5 cc. of water, 3 g. of NH_4Cl and 5 cc. of HCl saturated with bromine; digest (covered) on steam bath about 15 minutes, add 25 cc. of water, neutralize with dry Na_2CO_3, and add about 2 g. more, boil 10 to 15 minutes; let settle, dilute with hot water, filter and wash with hot water; redissolve in HCl, reprecipitate as above and wash thoroughly with hot water; acidify united filtrates with HCl, adding a slight excess; boil and add slight excess of 10-per-cent barium-chloride solution. Let stand on steam bath 1 hour, filter, wash with hot water, ignite, and weigh $BaSO_4$. Calculate to SO_3 (includes SO_3 formed from SO_2). Or, dissolve 0.5 g. of the sample in 25 cc. of water, 10 cc. of NH_4OH (sp. gr. 0.90) and HCl in slight excess; dilute to about 150 cc. with water and add a piece of aluminum foil which should about cover the bottom of the beaker—this held on bottom by means of a stirring rod. Heat gently till all lead is precipitated, decant through a filter, pressing the lead sponge with a flattened rod, and washing with hot water. Add to the filtrate a little pure bromine water, boil until bromine is expelled, add 15 cc. of 10-per-cent barium-chloride solution, let stand on steam bath one hour, filter, wash with hot water, ignite and weigh as $BaSO_4$ (any $SrSO_4$ present is not decomposed in this method).[1]

Soluble Zinc Sulfate.—Heat nearly to boiling 2 g. of the sample with 150 cc. of water and 50 cc. of 95-per-cent alcohol for 30 minutes, filter, and wash with a mixture of alcohol and water (1:3). Heat filtrate to boiling and expel most of the alcohol; then determine SO_3 by usual method of precipitation with $BaCl_2$. Calculate to $ZnSO_4$ and to SO_3.

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[1] The solubility of $BaSO_4$ is increased by the presence of aluminium chloride. See J. W. Mellor, "A Treatise on Quantitative Inorganic Analysis," p. 615.

NOTE.—If sample contains Ca or Mg, the Pb and Zn should be separated by precipitation with H_2S after dissolving in HCl, making alkaline with NH_4OH and acid with acetic acid. The PbS+ZnS is dissolved in dilute HNO_3 and the Pb and Zn determined as above.

Sulfur Dioxide.—Determine as under "Basic Sulfate of Lead" or "Zinc Oxide."

ZINC OXIDE.

Total Zinc.—Dissolve 0.25 to 0.3 g. in 10 cc. of concentrated HCl and 20 cc. of H_2O, make alkaline with NH_4OH, then acid with HCl, add 3 cc. more of concentrated HCl, dilute to about 250 cc. with H_2O, heat nearly to boiling and titrate with standard potassium-ferrocyanide solution as described by Low.[1] Report as ZnO (includes Cd). Iron, copper or other interfering substances should be first removed as described by Low.

Total Soluble Sulfur.[2]—Moisten a 10-g. sample with water, add a few drops of bromine and then concentrated HCl, boil to expel bromine, filter from any insoluble and wash with hot water. Make alkaline with NH_4OH, then just slightly acid with HCl, heat to boiling and add about 15 cc. of hot barium-chloride solution. Let stand several hours (over night), filter on a weighed Gooch crucible, wash well with hot water, dry, ignite for five minutes, cool and weigh as $BaSO_4$. Calculate to S.

Sulfur Dioxide.[2]—Mix 5 g. of sample with 50 cc. of warm (freshly boiled and then partly cooled) water to an emulsion and pour into a glass-stoppered flask containing 18 cc. of HCl and exactly 25 cc. of 0.1-normal iodine solution, stopper and shake until all the oxide is dissolved. Titrate the excess of iodine as rapidly as possible with 0.1-normal sodium-thiosulfate solution. Calculate to SO_2.

Soluble Zinc Sulfate.—Determine as under "Zinc-Lead and Leaded-Zincs."

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[1] Low, "Technical Methods of Ore Analysis."

[2] Method of G. Rigg.

LITHOPONE.

PONOLITH, JERSEY LILY WHITE, BECTON WHITE,
CHARLTON WHITE, ORR'S WHITE.

Insoluble and Total Zinc.—Take 1 g. of the sample in a 200-cc. beaker, add 10 cc. of concentrated HCl, mix, and add in small portions about 1 g. of $KClO_3$, then heat on the steam bath until about half of the liquid is evaporated. Dilute with H_2O, add 5 cc. of dilute H_2SO_4 (1:10); boil, let settle, filter, wash, ignite, cool, and weigh the insoluble which should be only $BaSO_4$; make a qualitative examination for alumina and silica. The insoluble should be examined under the microscope for the presence of natural crystallin barytes. Sample may also be examined direct. Make filtrate from insoluble alkaline with NH_4OH, acid with HCl, add 3 cc. of concentrated HCl, dilute to about 250 cc. with H_2O, heat nearly to boiling and titrate with $K_4Fe(CN)_6$ solution as under zinc white. Calculate to Zn.

Zinc Oxide.—Treat a 4-g. sample of the lithopone for 4 hours with 200 cc. of 1-per-cent acetic acid at room temperature, stirring occasionally. Filter by suction on a double filter paper and wash with cold water; add to the clear filtrate 13 cc. of concentrated NH_4OH, neutralize with HCl and then add 3 cc. of concentrated HCl in excess. Heat to boiling and titrate with $K_4Fe(CN)_6$, using uranium-acetate solution as an outside indicator. Calculate to ZnO. Calculate this result to Zn, subtract from total Zn, and calculate the difference to ZnS. (Any $ZnCO_3$ or $ZnSO_4$ is included in the ZnO.)

Zinc Sulfide.[1]—Place 0.5 g. of pigment in evolution flask with about 10 g. of "feathered" or mossy zinc, add 50 cc. of water; insert the stopper carrying a separatory funnel and an exit tube. Run in 50 cc. of concentrated HCl from the funnel, having previously connected the exit tube to two absorption flasks in series; first flask contains 100 cc. of alkaline lead-nitrate solution, second flask, 50 cc. of same as a safety device. After all of the acid has run into the evolution flask, heat slowly, finally boiling until the first appearance of steam in the first absorption flask; disconnect, let the lead sulfide settle, filter, wash with cold water, then with hot water till neutral to litmus paper and washings give no test for lead. The PbS precipitate is dissolved in hot, dilute HNO_3, evaporated to fumes with

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[1] Evolution Method of W. G. Scott, "White Paints and Painting Material," p. 257; see also Blair, "Chemical Analysis of Iron."

H_2SO_4 and finally weighed as $PbSO_4$. Calculate PbS or $PbSO_4$ to ZnS.

The alkaline lead solution is made as follows: Into 100 cc. of KOH solution (56 g. in 140 cc. of H_2O) pour a saturated solution of lead nitrate (250 g. in 500 cc. of H_2O) until the precipitate ceases to redissolve, stirring constantly while mixing. About 3 volumes of the lead solution will be required for one of the alkali.

Instead of absorbing the evolved H_2S in alkaline lead-nitrate solution, a solution of 8 g. of cadmium chloride in 250 cc. of water and 150 cc. of NH_4OH (sp. gr. 0.90) may be used. The CdS precipitate may be filtered on a weighed Gooch, washed with water containing a little NH_4OH, dried at 100° C., and weighed. Calculate to ZnS. It is better to filter the CdS on a small filter and wash as above, then place filter and precipitate in a beaker and dissolve in HCl and $KClO_3$ (keeping at room temperature at first), filter out any paper pulp or insoluble matter; make filtrate alkaline with NH_4OH, then just acid with HCl, heat to boiling and precipitate with $BaCl_2$ in usual manner. Filter, wash, ignite, and weigh $BaSO_4$. Calculate to ZnS.

For very rapid work the contents of the absorption flask, after all H_2S has been absorbed, may be washed into a vessel with *cold* water and diluted to about one liter, acidified with concentrated HCl and titrated with standard iodine solution, using starch indicator. (The precipitate should be completely dissolved.) The iodine solution is prepared by dissolving about 12.7 g. of pure resublimed iodine and 18 g. of KI in a little water and then diluting to one liter.

CALCIUM PIGMENTS.

WHITING, PARIS WHITE, SPANISH WHITE, AND CHALK.

Make a qualitative examination first; should contain only small amounts of insoluble matter (siliceous), iron, aluminum, sulfur, water or magnesium, and should be approximately 95 per cent $CaCO_3$.

Total Soluble Lime.[1]—Weigh out 0.75 g. of the pigment into a small crucible, ignite cautiously to dull redness to destroy organic matter, cool, transfer to a 400-cc. beaker, add 20 cc. of H_2O, cover, then add 15 cc. of concentrated HCl and 3 or 4 drops of concentrated HNO_3, and boil till all the soluble matter is dissolved and all the CO_2 expelled. Wash off and remove the cover, dilute to about 150 cc. with freshly boiled H_2O, heat to boiling and add dilute NH_4OH (sp. gr. 0.96) carefully until a *slight* permanent precipitate forms. Heat to boiling and add 10 cc. of a 10-per-cent solution of oxalic acid; stir until the oxides of iron and aluminum are entirely dissolved and only a slight precipitate of calcium oxalate remains. Now add 200 cc. of boiling H_2O and sufficient saturated solution of ammonium oxalate (20 to 25 cc.) to precipitate the lime. Boil and stir for a few moments, remove from the heat, let settle and filter on an 11-cm. filter. Wash 10 times with 10-to-15-cc. portions of hot water. Place beaker in which precipitation was made under the funnel, pierce apex of filter with stirring rod and wash precipitate into beaker with hot water, pour warm dilute H_2SO_4 (1:4) through paper and wash a few times; add about 30 cc. of the dilute H_2SO_4 (1:4), dilute to about 250 cc., heat to 90° C. and titrate at once with standard $KMnO_4$ solution (solution should not be below 60° C. when end-point is reached). The $KMnO_4$ is best standardized against Bureau of Standards sodium oxalate.[1] Calculate to CaO and $CaCO_3$.

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[1] Meade, "Portland Cement."

Mixed Calcium and Magnesium Carbonates.[2]—Weigh 1 g. of the finely powdered sample into a small porcelain dish, add 25 cc. of normal HCl, cover with a watch glass, and when effervescence has ceased, heat to boiling. Cool and titrate with normal NaOH solution, using methyl orange as indicator.

The calculation is as follows:

One gram CaO = 35.7 cc. of normal acid. $CaO \times 1.7844 = CaCO_3$. Subtract number of cubic centimeters of NaOH required from 25, result gives number of cubic centimeters of normal acid corresponding to the $CaCO_3+MgCO_3$. Multiply the weight of CaO in 1 g. of sample (as found in preceding section on total soluble lime) by 35.7; product gives number of cubic centimeters of normal acid corresponding to the CaO present; subtract from total number of cubic centimeters of acid required by $CaCO_3+MgCO_3$ and multiply result by 0.042, obtaining weight of $MgCO_3$ in 1 g. of sample. The $MgCO_3$ determined by this process should not differ more than 0.25 per cent from that obtained by more elaborate methods. It is to be noted that this method is a measure of the total alkalinity, and if Ca or Mg are present in other forms than carbonate, a complete analysis would be necessary to give percentages of $CaCO_3$ and $MgCO_3$.

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[1] *Circular No. 40*, Bureau of Standards.

[2] J. W. Mellor, "A Treatise on Quantitative Inorganic Analysis," p. 522.

Instead of the above, Newberry's[1] method for the simultaneous determination of calcium and magnesium carbonates may be used.

GYPSUM, TERRA ALBA, PLASTER OF PARIS.

Combined Water and Moisture.—Heat 1 g. of the sample in a covered porcelain crucible on an asbestos plate for 15 minutes, then heat bottom of crucible *dull red* for 10 minutes over a Bunsen burner, remove cover and heat for 30 to 40 minutes at a slightly lower temperature. Cool and weigh rapidly. Repeat to constant weight.

Combined water and moisture may also be determined by heating in an air bath at 200° C. to constant weight.

Insoluble Matter.—Boil 2 to 3 g. of the sample with 20 cc. of concentrated HCl, a few drops of HNO_3, and about 50 cc. of water; evaporate to dryness, boil residue repeatedly with 10-per-cent HCl, decanting through a filter; finally transfer to the filter, wash with hot water, ignite and weigh insoluble matter; test for $BaSO_4$. Make a qualitative examination of the filtrate from the insoluble matter to determine if Al, Fe, or Mg are present in abnormal amounts (should be mainly Ca and SO_3). Test a separate portion of the sample for CO_2; if desired determine as under "Basic Carbonate of Lead."

BARIUM PIGMENTS.

BARYTES OR BARITE, "BLANC FIXE."

Examine the sample microscopically to determine uniformity of grinding, size and angularity of particles, crystallin or amorphous. The sample should be at least 95 per cent $BaSO_4$.

Loss on Ignition.—Ignite 1 g. of the sample for 30 minutes. Loss may be due to organic matter, moisture, combined water and CO_2 (and SO_3 from $CaSO_4$ if present). If loss is appreciable, test for CO_2.

Soluble and Insoluble Matter.—Boil 1 g. with HCl (1:3), filter, wash with hot water, ignite, and weigh insoluble matter.

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[1] Meade, "Portland Cement"; Mellor, "A Treatise on Quantitative Inorganic Analysis," p. 522; *Cement Engineering News*, Vol. 15, p. 35 (1903).

This may be treated with H_2SO_4 and HF in usual manner for SiO_2. In the absence of Al_2O_3 (from silicates) residue is considered as $BaSO_4$. Make qualitative tests of filtrate from the insoluble for Al, Fe, Ca, Mg, SO_3. Test a separate portion of sample qualitatively for CO_2.

SILICA PIGMENTS.

SILICA OR SILEX.

Silica or silex should be practically pure SiO_2. A qualitative examination will suffice in most cases with a determination of the loss on treating 1 g. of sample with H_2SO_4 and HF in usual manner.

CHINA CLAY AND ASBESTINE.

A qualitative analysis of China clay to determine if essentially hydrous aluminium silicate is generally all of the chemical tests necessary. Color, fineness, etc., are more important than analysis.

Asbestine is tested qualitatively to prove that material is as represented. Color, fineness, etc., are important. Asbestine should be examined under the microscope to note whether it is fibrous or talcose and whether silica or China clay are admixed. Samples of known origin should be used here as a guide for comparison.

STANDARD METHODS OF ROUTINE ANALYSIS
OF
DRY RED LEAD.

Serial Designation: D 49 – 18.

These methods are issued under the fixed designation D 49; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted, 1918.

1. The approximate formula of Red Lead is Pb_3O_4 (probably $PbO_2 \cdot 2PbO$).

Specific Gravity.

Specific Gravity

2. True specific gravity shall be determined by Thompson's method,[1] or by means of a 50-cc. pyknometer, using c p. benzine and 20 g. of pigment.

Moisture.

Moisture.

3. Dry 2 g. of the sample for 2 hours at 105° C. The loss in weight is considered as moisture.

Organic Color.

Organic Color.

4. Boil 2 g. of the sample with 25 cc. of 95-per-cent ethyl alcohol, let settle, decant off the supernatant liquid; boil residue with water, decant as before and boil residue with very dilute NH_4OH. If either the alcohol, water or NH_4OH is colored, organic coloring matter is indicated.

Total Lead and Insoluble Matter.

Total Lead and Insoluble Matter.

5. Treat 1 g. of the sample with 15 cc. of HNO_3 (1 : 1) and sufficient H_2O_2 to dissolve all PbO_2 on warming. If any insoluble matter is present, add 25 cc. of water, boil, filter and wash with hot water. The insoluble matter contains free SiO_2 and should be examined for $BaSO_4$ and silicates, if appreciable. To the original solution or filtrate from insoluble, add 20 cc. of concen-

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[1] *Proceedings* Am. Soc. Test. Mats., Vol. XIII, p. 407 (1913).

trated H_2SO_4 and evaporate to SO_3 fumes; cool, add 150 cc. of water and 150 cc. of 95-per-cent ethyl alcohol, let stand *cold* 2 hours, filter on a Gooch crucible, wash with 95-per-cent alcohol, dry at 105 to 110° C. and weigh as $PbSO_4$. Calculate to PbO. Red lead is rarely adulterated, but should sample contain soluble barium compounds, the $PbSO_4$ obtained above will contain $BaSO_4$. In this case, digest above precipitate with acid ammonium-acetate solution, filter off $BaSO_4$, wash, ignite and weigh $BaSO_4$. Calculate to BaO or $BaCO_3$. In filtrate, determine the lead as $PbSO_4$ or $PbCrO_4$. If sample contains significant amounts of calcium or magnesium, the HNO_3–H_2O_2 solution is boiled till all lead is converted into nitrate and then the lead is determined as $PbCrO_4$.

If calcium and magnesium are to be determined, proceed as follows: Precipitate the lead as sulfide from a slightly acid (HCl) solution, dissolve the PbS in hot dilute HNO_3 and determine the lead as sulfate. Boil the filtrates from the PbS to expel H_2S, add a little bromine water to oxidize iron (if present), boil to expel bromine, and then add NH_4OH in slight excess. Filter off any precipitate of $Fe(OH)_3+Al(OH)_3$; wash with hot water. (If appreciable, redissolve in hot dilute HCl and reprecipitate with NH_4OH, ignite and weigh $Fe_2O_3+Al_2O_3$.) Manganese, if present, can be precipitated by adding bromine and NH_4OH and warming; filter, wash with hot water, ignite and weigh as Mn_3O_4. Unite all of the filtrates, make slightly acid with acetic acid, heat to boiling and pass H_2S into the hot solution till saturated (20 to 30 minutes); add 5 g. of NH_4Cl and let stand 5 hours; filter off any ZnS, wash with H_2S water. dissolve the ZnS in hot dilute HCl and determine the zinc by titration with $K_4Fe(CN)_6$. Or, boil off the H_2S, filter out any separated sulfur and determine the zinc as $Zn_2P_2O_7$. Calcium may be determined in the filtrate from the ZnS by expelling H_2S and then adding NH_4OH and ammonium oxalate in the usual manner. Titrate with $KMnO_4$. In the filtrate from calcium determine magnesium in the usual manner by precipitating with sodium-phosphate solution, finally weighing as $Mg_2P_2O_7$.

Lead Peroxide (PbO_2) and True Red Lead (Pb_3O_4).

(Method of Diehl[1] modified by Topf[2]—not applicable when substances are present, other than oxides of lead, that liberate iodine under conditions given.)

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[1] *Dingl. polyt. Jour.*, Vol. 246, p. 196.

[2] *Zeitschrift für analytische Chemie*, Vol. 26, p. 296.

Lead Peroxide and True Red Lead.

6. Weigh 1 g. of finely ground sample into a 200-cc. Erlenmeyer flask, add a few drops of distilled water and rub the mixture to a smooth paste with a glass rod flattened on end. Mix in a small beaker 30 g. of c. p. "Tested Purity" crystallized sodium acetate, 2.4 g. of c. p. KI, 10 cc. of water and 10 cc. of 50-per-cent acetic acid; stir until all is liquid, warming gently; if necessary add 2 to 3 cc. of water, cool to room temperature and pour into the flask containing the red lead. Rub with the glass rod until nearly all the red lead has been dissolved; add 30 cc. of water containing 5 or 6 g. of sodium acetate, and titrate at once with decinormal sodium thiosulfate, adding the latter rather slowly and keeping the liquid constantly in motion by whirling the flask. When the solution has become light yellow, rub any undissolved particles up with the rod until free iodine no longer forms, wash off rod, add the sodium-thiosulfate solution until *pale yellow*, add starch solution and titrate until colorless, add decinormal iodine solution until blue color is just restored and subtract the amount used from the volume of sodium thiosulfate that had been added.

Calculation.—The iodine value of the sodium-thiosulfate solution multiplied by $0.94193 = PbO_2$; the iodine value multiplied by $2.69973 = Pb_3O_4$; the PbO_2 value multiplied by $2.86616 = Pb_3O_4$.

The sodium-thiosulfate solution and the starch solution shall be prepared as follows:

Sodium-Thiosulfate Solution (*decinormal*).—Dissolve 24.83 g. of c. p. sodium thiosulfate, freshly pulverized and dried between filter paper, and dilute with water to 1 liter at the temperature at which the titrations are to be made. The solution is best made with well-boiled water free from CO_2, or let stand 8 to 14 days before standardizing. Standardize with pure, re-sublimed iodine, as described in Treadwell-Hall, "Analytical Chemistry," Vol. II, p. 602 (1910), and also against pure potassium iodate; the two methods of standardization should agree within 0.1 per cent on iodine value.

Starch Solution.—Stir up 2 to 3 g. of potato starch with 100 cc. of 1-per-cent salicylic-acid solution, and boil the mixture till starch is practically dissolved, then dilute to 1 liter,[1] or as per Lord.[2]

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[1] *Lead Peroxide.*—If sample contains an appreciable amount of nitrite (nitrate has no effect on method), leach out water-soluble matter as below, dry residue and determine PbO_2 as above, calculating to basis of original sample.

[2] "Notes on Metallurgical Analysis," p. 103 (1903).

DETERMINATION OF ZINC.

Zinc.

7. If in appreciable amount, evaporate off the alcohol from the filtrate from total lead, make alkaline with NH_4OH, then acid with HCl, add 3 cc. more of concentrated HCl, dilute to about 250 cc. with water, heat nearly to boiling and titrate with standard $K_2Fe(CN)_6$ solution as described by Low.[1] Report as ZnO (includes cadium). Iron, copper or other interfering substances should first be removed as described by Low.

WATER-SOLUBLE.

Water-Soluble.

8. Digest 10 g. of sample with 200 cc. of hot water on steam bath for 1 hour; filter on an 11-cm. S. & S. blue-ribbon paper and wash with hot water till no residue is left on evaporating a few drops of the washings. Evaporate filtrate to dryness on steam bath in a weighed dish, dry 30 minutes at 105° C., cool and weigh. Take up with water and if alkaline, titrate with tenth normal acid and methyl orange; calculate to Na_2CO_3.

Another lot of water-soluble matter is tested for nitrates, nitrites, carbonates, sulfates, sodium and lead.

TOTAL SILICA.

Total Silica.

9. Digest 5 g. of the sample in a covered casserole with 5 cc. of HCl and 15 cc. of HNO_3 (1 : 1). Evaporate to dryness to dehydrate. Cool, treat with hot water and HNO_3, boil, filter, wash with hot acid ammonium-acetate solution, then dilute HCl and finally hot water. Ignite and weigh as SiO_2. The residue may be treated with H_2SO_4 and HF in cases of doubt as to purity.

CARBON DIOXIDE.

Carbon Dioxide.

10. Determine carbon dioxide by the evolution method, using dilute HCl and stannous chloride.

DETERMINATION OF SOLUBLE SULFATE.

Soluble Sulfate.

11. *Sulfates other than Barium Sulfate.*—Treat 0.5 g. of the sample with 5 cc. of water, 3 g. of NH_4Cl and 5 cc. of HCl saturated with bromine; digest (covered) on steam bath about 15 minutes, add 25 cc. of water, neutralize with dry Na_2CO_3, and add about 2 g. more, boil 10 to 15 minutes; let settle, dilute with hot water, filter and wash with hot water; redissolve in

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[1] Low, "Technical Methods of Ore Analysis."

HCl, reprecipitate as above and wash thoroughly with hot water; acidify united filtrates with HCl, adding a slight excess; boil and add slight excess of 10-per-cent $BaCl_2$ solution. Let stand on steam bath 1 hour, filter, wash with hot water, ignite, and weigh $BaSO_4$. Calculate to SO_3 (includes SO_3 formed from SO_2).

Or, dissolve 0.5 g. of the sample in 25 cc. of water, 10 cc. of NH_4OH (sp. gr. 0.90) and HCl in slight excess; dilute to about 150 cc. with water and add a piece of aluminum foil which should about cover the bottom of the beaker—this held on bottom by means of a stirring rod. Heat gently till all lead is precipitated, decant through a filter, pressing the lead sponge with a flattened rod, and washing with hot water. Add to the filtrate a little pure bromine water, boil until bromine is expelled, add 15 cc. of 10-per-cent $BaCl_2$ solution, let stand on steam bath one hour, filter, wash with hot water, ignite and weigh as $BaSO_4$ (any $SrSO_4$ present is not decomposed in this method).[1]

IRON OXIDE.

Iron Oxide. 12. Determine iron oxide by Schaeffer's[2] modification of Thomson's colorimetric method; or, in a large beaker, treat 20 g. of the sample with 20 cc. of water, 20 cc. of HNO_3 (sp. gr. 1.4) and 3 cc. of formaldehyde solution. Warm till all PbO_2 is dissolved, dilute with water, warm, filter off insoluble and wash with hot water. Ignite filter and insoluble, evaporate with H_2SO_4 and HF. To filtrate from insoluble add 14 cc. of H_2SO_4 (1 : 1), filter off $PbSO_4$, and wash. Dissolve residue from HF and H_2SO_4 in H_2SO_4 and add to filtrate from $PbSO_4$; dilute to 500 cc. and determine iron colorimetrically in an aliquot, using same amounts of HNO_3, H_2SO_4 and formaldehyde in comparison solution.[3] Calculate to Fe_2O_3.

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[1] The solubility of $BaSO_4$ is increased by the presence of aluminum chloride. See J. W. Mellor, "A Treatise on Quantitative Inorganic Analysis," p. 615.

[2] *Journal of Industrial and Engineering Chemistry*, Vol. 4, p. 659 (1912).

[3] Lunge-Berl, "Chemisch-technische Untersuchungs-Methoden," Bd. 2, S. 95, 6th Ed.

STANDARD METHODS OF ROUTINE ANALYSIS OF YELLOW, ORANGE, RED, AND BROWN PIGMENTS CONTAINING IRON AND MANGANESE.

Serial Designation: D 50 - 18.

These methods are issued under the fixed designation D 50; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted, 1918.

GENERAL METHODS.

Specific Gravity.

Specific Gravity.

1. True specific gravity shall be determined by Thompson's method,[1] or by means of a 50-cc. pyknometer, using c. p. benzine and 10 to 20 g. of pigment.

Tinting Strength.[2]

Tinting Strength.

2. The colors should always be compared with a carefully selected standard. Weigh out accurately from 0.02 to 0.05 g. of color, place on a large glass plate, add 12 drops of bleached linseed oil,[3] and rub up with a flat-bottom glass pestle or muller; then add 1 g. of pure ZnO, and grind with a circular motion 50 times; gather up with a sharp-edge spatula and grind out twice more in like manner, giving the pestle a uniform pressure. Next weigh out a similar amount of the standard, and treat in exactly the same manner as described above. Transfer portions of each paste to a microscope slide, quite close together, and then draw a palette knife across both samples so as to make them meet in a line (differences in tint are then easily seen). Compare the tints as shown on both sides of the glass. The amount of pigment used will vary with the tinting strength, but generally it suffices to take about 0.02 g. of the reds and about 0.05 g. of the ochers.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XIII, p. 407 (1913).

[2] Holley, "Analysis of Paint and Varnish Products," 1912, p. 126.

[3] The use of "oxidized" oil should be avoided (oil that has become "fatty" by standing around in a can or bottle). Poppy-oil could be used but it is quite as necessary to have it reasonably fresh as when linseed oil is used. In either case "stringy" pastes are not reliable.

If it is desired to express quantitatively the tinting strength of the pigment, consider the standard pigment as having a tinting strength of 100, and then vary the amount of the standard pigment until the tints are matched.

For example, let the amount of standard pigment for 100 strength test be 0.02 g. (= A). Vary this amount in units of 5 per cent, thus 0.019 or 0.021. Let the amount taken to match a given strength = B, then

$$\frac{B}{A} \times 100$$

equals the tinting strength of the sample to be tested.

If the tone varies it may be difficult to make this measurement.

ADDED COLORING MATTER.

Added Coloring Matter.

3. Test the pigment successively with hot water, 95-per-cent ethyl alcohol, alcoholic NaOH or KOH and acetic acid. Chloroform, NaOH, H_2SO_4, HCl-stannous chloride, and other reagents may be tried.[1] The presence of an organic color may often be noted by the characteristic odor given off on ignition.

METHODS FOR ANALYSIS OF INDIAN REDS, RED OXIDES (PRINCE'S METALLIC, TUSCAN RED).

LOSS AT 100° C.

Loss at 100° C.

4. Heat 2 g. in a steam-jacketed oven at atmospheric pressure for three hours, or to constant weight.

LOSS ON IGNITION.

Loss on Ignition.

5. Ignite a portion in a covered porcelain crucible to constant weight. This may include combined water, CO_2, organic matter, and some SO_3 if much $CaSO_4$ is present. CO_2 may be determined on a separate portion of the sample if desired.[2]

FREE ACID OR ALKALI.

Free Acid or Alkali.

6. Boil 10 g. of sample with 100 cc. of water; filter and wash. Test filtrate with litmus paper; if acid, titrate with standard alkali and methyl orange and calculate to the equivalent of H_2SO_4. If alkaline, titrate with acid and calculate to the equivalent of Na_2O. Test filtrate for alkali salts and alkaline earths.

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[1] For details consult Zerr, "Tests for Coal-Tar Colors in Aniline Lakes," (English translation by C. Mayer); Schultz and Julius, "A Systematic Survey of the Organic Coloring Matters;" Hall, "The Chemistry of Paints and Paint Vehicles;" and Mulliken, "Identification of Pure Organic Compounds," *Commercial Dyestuffs*, Vol. III.

[2] It is inadvisable to use platinum unless it is known that attacking substances are absent.

ADDED COLORING MATTER.

Added Coloring Matter.

7. Test as under "General Methods."

INSOLUBLE, IRON OXIDE, ETC.

Insoluble, Iron Oxide, etc.

8. Digest 2.5 g. of the sample (previously roasted at a low temperature if much organic matter is present; if very low in carbonaceous matter a little $KClO_3$ or $NaClO_3$ may be used in effecting solution) with 25 cc. of HCl (adding a little HNO_3 or chlorate, if not already added), wash off cover, and evaporate to dryness. Take up with HCl and water, filter, wash with dilute HCl and cold water. Make the filtrate up to 500 cc., mix, and examine as below.[1] Ignite the residue and weigh as "insoluble matter";[2] if this contains $BaSO_4$ it may be determined by fusing with six times its weight of Na_2CO_3, cooling, digesting with hot water, filtering, and washing the residue with hot water until free of sulfate.

Remove filtrate and place beaker used for the digestion underneath the funnel, pierce the filter with the glass rod, and wash the residue with a little water into the beaker; then pour hot dilute HCl (1 : 1) over paper, and finally wash with hot water. If necessary add more HCl to the beaker to dissolve the $BaCO_3$; heat to boiling, add dilute H_2SO_4 in slight excess, let stand about one hour on steam bath; filter, wash, dry, ignite, and weigh $BaSO_4$. (This subtracted from total insoluble will give "insoluble silicious matter," if it is desired to so report.) If it is desirable to analyze the insoluble silicious matter, this can be done by the usual methods for silicate analysis, but the results should be reported as a separate analysis.

For the determination of iron place 100 cc. of the first filtrate in a flask, add about 3 g. of granulated zinc, put a funnel into the neck of the flask, heat when the action slackens; if basic salts separate out add a few drops of HCl. When the reduction is complete, add 30 cc. of H_2SO_4 (1 : 2), and as soon as the residual zinc is dissolved, wash down the funnel inside and out and the neck of the flask with a fine jet of water, filling the flask (1000 cc.) about two-thirds full, cool in water, add 10 cc. of "titrating solution" (made by dissolving 160 g. of manganese sulfate in water, diluting to 1750 cc., adding 330 cc. of H_3PO_4, sp. gr. 1.72, and 320 cc. of concentrated H_2SO_4), and titrate with

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[1] For more exact work this filtrate should be evaporated to dryness and SiO_2 removed.

[2] If the insoluble contains appreciable amounts of Fe it will be necessary to fuse it with Na_2CO_3 or $K_2S_2O_7$ to determine total Fe in samples.

$KMnO_4$ (5.659 g. per liter) that has been standardized against Bureau of Standards sodium oxalate. Run a blank on the zinc, correct for same and calculate total iron as Fe_2O_3. Instead of adding the zinc to the solution, the reduction may be effected in a zinc reductor.[1]

The Fe_2O_3 may also be determined by the $K_2Cr_2O_7$ method.[2]

LIME.

Lime.

9. Dilute an aliquot of 100 cc. of the original solution to about 200 cc., add 10 cc. of HCl, make alkaline with HN_4OH, add 2 or 3 cc. of bromine water, and boil till excess of NH_3 is expelled. Let settle, wash by decantation, redissolve in HCl, and reprecipitate with NH_4OH and bromine water. (Precipitate = $Fe_2O_3 . Al_2O_3 . TiO_2 . P_2O_5 . MnO_2$.) This precipitate may be ignited and weighed if desired.

To the combined filtrates add a few drops of NH_4OH, heat to boiling, and add an excess of saturated ammonium-oxalate solution; continue the boiling until the precipitate becomes granular, let stand about 30 minutes, filter, and wash with hot water till free of ammonium oxalate;[3] place beaker in which precipitation was made under the funnel, pierce apex of filter with stirring rod and wash precipitate into beaker with hot water, pour warm dilute H_2SO_4 (1 : 4) through paper and wash a few times; add about 30 cc. of H_2SO_4 (1 : 4), dilute to about 250 cc., heat to 90° C. and titrate at once with standard $KMnO_4$ solution (solution should not be below 60° C. when end-point is reached). Calculate to CaO. (The Fe value of $KMnO_4 \times 0.502 = CaO$.) The calcium-oxalate precipitate may be ignited to constant weight as CaO. If desired, magnesia may be determined as $Mg_2P_2O_7$ in the usual manner in the filtrate from the calcium oxalate.[4]

SOLUBLE SULFATES.

Soluble Sulfates.

10. Treat 1 g.[5] of the pigment (roasted gently if much organic matter is present) with 30 cc. of HCl, boil 10 minutes, add about 50 cc. of water, boil, filter, and wash with hot water. Heat the

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[1] Lord and Demorest, "Metallurgical Analysis," 1913, pp. 28–29.

[2] *Ibid.*, pp. 21–26

[3] For more exact work this precipitate should be dissolved in HCl and the calcium oxalate reprecipitated as above.

[4] If desired, a direct determination of Al_2O_3 may be made on an aliquot of the solution or on the HCl solution of the NH_4OH precipitate by Peters' phosphate method (this will include titanic acid) as described by Blair, "The Chemical Analysis of Iron," and Philips, "Methods of Iron Analysis Used in the Pittsburgh District."

[5] If low in soluble sulfates use a larger portion of sample.

solution to boiling, add NH_4OH, filter and wash a few times with hot water; dissolve precipitate in hot dilute HCl and reprecipitate with NH_4OH, wash well with hot water. Render united filtrates just distinctly acid with HCl, boil, add by drops with stirring excess of 10-per-cent $BaCl_2$ solution, boil about 10 minutes, filter on a Gooch crucible, wash with hot water, ignite and weigh as $BaSO_4$. Calculate to SO_3 or $CaSO_4$.

TOTAL SULFUR OTHER THAN THAT PRESENT AS $BaSO_4$.

Total Sulfur.

11. Treat 5 g. of the sample in a covered porcelain dish with 50 cc. of aqua regia (1 HNO_3 : 9 HCl) and evaporate to dryness on steam bath. Add 20 cc. of concentrated HCl and about 250 cc. of water, make double NH_4OH precipitation; determine $BaSO_4$ as given under "Soluble Sulfates."

METHODS FOR ANALYSIS OF OCHERS.

12. Loss at 100° C., loss on ignition, insoluble matter, total or soluble iron, alumina, lime and sulfur may be determined as outlined under the "Methods for Analysis of Indian Reds, etc.," using 1 g. or an aliquot corresponding to this weight.

TINTING STRENGTH.

Tinting Strength.

13. Test as under "General Methods." Tests should be made for solubility in water, and reaction to litmus paper.

LEAD CHROMATE.

Lead Chromate.

14. If present, the lead is removed in the above scheme by nearly neutralizing the filtrate from the insoluble matter with NH_4OH, cooling, and passing in H_2S, to precipitate PbS. Filter, wash with water containing H_2S, dissolve PbS in hot dilute HNO_3, add 10 cc. of concentrated H_2SO_4, evaporate till SO_3 is evolved, cool, dilute to 200 cc., let stand a few hours, filter on a Gooch crucible, wash with 1-per-cent H_2SO_4, ignite, and weigh $PbSO_4$. Calculate to PbO or Pb. Heat the filtrate from the PbS to expel H_2S, oxidize with a little HNO_3, and make up to volume if working on more than 1 g.

The iron is best determined in an aliquot by the $K_2Cr_2O_7$ method. Another aliquot is treated with NH_4OH, the precipitate containing $Al_2O_3.Fe_2O_3.Cr_2O_3.P_2O_5.TiO_2$. Lime and MgO may be determined in filtrate.

The NH_4OH precipitate is dissolved in hot dilute HCl, washing paper with hot water, *cooled*, oxidized with Na_2O_2, boiled to expel H_2O_2, cooled, cover glass washed off, diluted to about 150 cc., and acidified with H_2SO_4. Add a measured excess of ferrous ammonium-sulfate solution—$(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$, 12.4 g.; concentrated H_2SO_4, 50 cc.; and water to make 1 liter, and titrate back with standard $K_2Cr_2O_7$ solution, using $K_3Fe(CN)_6$ solution as an outside indicator. The $(NH_4)_2Fe(SO_4)_2.6H_2O$ solution is titrated with the $K_2Cr_2O_7$ solution to determine its value in terms of the latter. The Fe value of the $K_2Cr_2O_7$ solution $\times 0.5969 = CrO_3$.

Or, moisten 1 g. of the pigment with water, add 5 cc. of concentrated HCl, boil a few minutes, *cool*, add Na_2O_2 in excess, boil to expel H_2O_2, cool, wash off cover glass, dilute, acidify with H_2SO_4, and titrate CrO_3 as above.

VENETIAN RED.

Venetian Red.

15. Analyze as given under "Methods for Analysis of Indian Reds, etc." Insoluble matter may be treated with HF and H_2SO_4 to determine SiO_2 by loss if desired.

METHODS FOR ANALYSIS OF SIENNAS AND UMBERS.

16. After gently roasting to destroy organic matter, test as given under "Methods for Analysis of Indian Reds, etc."

MANGANESE.

Manganese.

17. Manganese is determined by the bismuthate method.[1] Ignite gently (to destroy organic matter) 1 g. of the sample in a platinum dish, cool, add 10 cc. of water, 4 cc. of concentrated H_2SO_4 and about 20 cc. of HF (if necessary, add a little sulfurous acid). Evaporate until the H_2SO_4 fumes freely, cool and dissolve in 25 cc. of HNO_3 (1 part concentrated HNO_3 to 3 parts water). If no appreciable residue remains, transfer to a 100-cc. volumetric flask, using 25 cc. of HNO_3 (1 : 3) to rinse the dish, dilute to the mark with water, mix thoroughly. If there is an appreciable residue, filter on a small filter, wash with water, ignite residue in a platinum crucible, and fuse with a little sodium or potassium pyrosulfate. Dissolve in water, with the addition of a little HNO_3, add to the main filtrate, evaporate nearly to dryness, take up in HNO_3 (1 : 3) and transfer to the flask as before. Pipette an aliquot of 10 cc. into a

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[1] Blair, "The Chemical Analysis of Iron."

200-cc. Erlenmeyer flask, add 30 cc. of water and 10 cc. of concentrated HNO_3, sp. gr. 1.4; add about 0.5 g. of sodium bismuthate, heat for a few minutes, or until the pink color has disappeared with or without the precipitation of MnO_2. Add a few small crystals of sodium or potassium nitrite to dissolve the MnO_2 and boil the solution several minutes to expel nitrous fumes (a little Na_2CO_3 will aid this). Add water to bring the volume up to 50 cc. and cool to about 15° C.; add about 0.5 g. of bismuthate and shake the flask well. Add 50 cc. of water containing 30 cc. of concentrated HNO_3 to the liter, filter by suction through an asbestos felt into a 300-cc. Erlenmeyer flask and wash with 50 to 100 cc. of the same acid. Run in a measured volume of standard ferrous ammonium-sulfate solution and titrate to a faint pink color with standard $KMnO_4$ solution. The number of cubic centimeters of the $KMnO_4$ solution obtained, subtracted from the number corresponding to the volume of ferrous solution used, will give the volume of $KMnO_4$ equivalent to the manganese in the sample, which, multiplied by the value of the $KMnO_4$ in Mn, gives the weight of manganese in the portion of sample used.

Standard $KMnO_4$ Solution.—The solution of $KMnO_4$ is composed of 1 g. dissolved in a liter of water. The Fe value of this solution $\times$ 0.1968 = Mn. This solution may be standardized against Bureau of Standards sodium oxalate (using about 0.05 to 0.1 g.)[1] Weight of $Na_2C_2O_4 \times 0.1639$ = Mn. Twelve grams of $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$, 25 cc. of concentrated H_2SO_4, and 25 cc. of H_3PO_4, sp. gr. about 1.7, are made up to 1 liter with water. The value of this solution should be determined against the $KMnO_4$ each day as follows:

Measure into a 200-cc. Erlenmeyer flask 50 cc. of HNO_3 (1 : 3), cool, add a little bismuthate, dilute with 50 cc. of 3-per-cent HNO_3, filter by suction through an asbestos felt into a 300-cc. Erlenmeyer flask, and wash with 50-cc. of 3-per-cent HNO_3. Run in 25 cc. of the ferrous solution and titrate with $KMnO_4$ solution. Instead of titrating the permanganic acid formed by the bismuthate with the ferrous solution and then titrating back with $KMnO_4$, a direct titration with standard sodium arsenite solution may be made.[2]

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[1] W. Blum, "Original Communications," Eighth International Congress of Applied Chemistry," Vol. I, pp. 61-85.

[2] Lord and Demorest, 'Metallurgical Analysis." 1913, p. 82.

STANDARD DEFINITIONS
OF
TERMS RELATING TO PAINT SPECIFICATIONS.

Serial Designation: D 16 – 15.

These definitions are issued under the fixed designation D 16; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1915.

Standard.—Materials, methods, qualities, properties, etc., set forth by specification as a basis for the measurement of requirements.

Equal To.—The use of this term should be avoided if possible.

The avoidance of this term is recommended wherever possible because the specifications themselves should state the qualities, etc., desired. In specifications having the sanction of the American Society for Testing Materials, it is to be assumed that this feature will be developed to its fullest extent.

Pure.—Free from admixture of any foreign substance.

Commercially Pure.—The use of this term should be avoided if possible.

The avoidance of this term is recommended wherever possible because it involves the acceptance of standards likely to cause dispute, whereas specifications having the sanction of the American Society for Testing Materials should involve the establishment of their own standards.

Adulteration.—The partial substitution of one substance for another without acknowledgment.

The addition of the words "without acknowledgment" makes this definition clear. Substitution with acknowledgment involves no improper motive. If it is done without acknowledgment an improper motive may be assumed.

Adulterant.—A substance substituted partially for another without acknowledgment.

Bulk.—The bulk of a pigment is the total volume thereof plus voids.

In referring to the bulk of a substance, it is often convenient to say: " Its bulk is (say) 10 g. to the cubic inch." In this case the word bulk is synonomous with "apparent density" and involves a determination by a specific method.

Voids.—The spaces between the particles of a pigment.

Opacity.—The degree of obstruction to the transmission of visible light.

In this sense "opacity" is a relative term, it being considered that given a film sufficiently thin, in paint technology at least, there is no absolutely opaque substance.

Covering Power.—The use of this term should be avoided if possible.

This term has been used so loosely that it might mean hiding power, spreading power, or the simple property of producing a coat.

Hiding Power.—The power of a paint or paint material as used to obscure a surface painted with it.

In this definition the word "obscure" means to render invisible or to cover up a surface so that it cannot be seen.

Spreading Rate.—The rate at which a paint or paint material, as used, is brushed out to a continuous uniform film expressed in terms of the area to which a unit volume, as used, is applied.

This term must not be confused with the much-abused term "spreading power." The use of the term "spreading rate" is illustrated in the following sentence: "The paint when spread on a planished iron surface at the rate of 600 sq. ft. to the gallon will not sag or run when placed in a vertical position at 70° F."

Fineness.—A term used to denote the extent of sub-division and expressive of the number of particles of pigment in a unit volume exclusive of voids.

According to this definition if pigment *A* has a specific gravity of 6 and pigment *B* a specific gravity of 2, and if these two pigments have equal fineness, in 6 g. of pigment *A* there would be the same number of particles as in 2 g. of pigment *B*.

Crystallin.—Having a definite structure referable to one of the crystallographic systems.

According to definition a material is not crystallin if it has not a crystallin form irrespective of the optical and other properties it may possess.

Amorphous.—Without regular or definite form.

This definition as given here has a broader meaning than it possesses when it is used in mineralogical writings. Protozoa, if of definite form, are not amorphous and may not be crystallin.

Paint.—A mixture of pigment with vehicle, intended to be spread in thin coats for decoration or protection, or both.

According to this definition a mixture of pigment and varnish is a paint, and on the other hand a solution of stains in oil or varnish, no pigment being present, is not a paint.

Pigment.—The fine solid particles used in the preparation of paint, and substantially insoluble in the vehicle.

Asphaltic materials are not pigments except when they contain substances substantially insoluble in the vehicle in which they are used.

Vehicle.—The liquid portion of a paint.

Here anything that is dissolved in the liquid portion of a paint is a part of the vehicle.

Volatile Thinner.—All that liquid portion of a paint, water excepted, which is volatile in a current of steam at atmospheric pressure.

Non-Volatile Vehicle.—The liquid portion of a paint excepting its volatile thinner and water.

Tinting Strength.—The power of coloring a given quantity of paint or pigment selected as a medium standard for estimating such power.

Color.—A generic term referring inclusively to all of the colors of the spectrum, white and black, and all tints, shades and hues which may be produced by their admixture.

Color involves a definite effect produced by the action of light upon the retina of the eye dependent upon the optical composition of the light. This term is also used in reference to material substances such as pigments, stains, dyes, etc., but in specifications it should be recognized that color is primarily a physiological sensation.

Tint.—A color produced by the admixture of a coloring material, not white, with a white pigment or paint, the white predominating.

Shade.—A term descriptive of that difference between colors which results from a difference in luminosity only, the other color constants being essentially equal. A darker shade of a color is one that has a lower luminosity.

Primarily the term "shade" is akin to shadow designating darkness or reduced illumination, and therefore when strictly used should express only such change as depends on *reduced* luminosity; it has been defined by several authorities as the mixture of black with a color, thus establishing its opposite character to "tint," but by extension of its relative sense it has been frequently and widely used to include lighter shades by use of the adjective "lighter" or "paler." Although such expressions apparently involve a contradiction, it is clear that while we may have a shade of color or darker color of the same sort, it is easy to conceive of another shade not quite so dark and therefore lighter.

Hue.—The predominating spectral color in a color mixture.

Tone.—The color which principally modifies a hue or a white or a black.

Drying.—The solidification of a film.

Drier.—A material containing metallic compounds added to paints and painting materials for the purpose of accelerating drying.

Specific Gravity.—The ratio of the weight of a unit volume of a substance to the weight of an equal volume of water at defined temperatures.

Density.—The use of this term should be avoided if possible.

Density is a scientific term meaning the mass of a unit volume. Its numerical expression will vary with the units selected, and there is no occasion for using it when the term "specific gravity" is defined. Confusion may be avoided by not using the word "density" in specications.

Gallon.—The measured gallon is 231 cu. in. Where a measured gallon is called for, the temperature at which it is to be measured should be specified. Where a gallon of definite weight is called for, the weight should be specified or obtained from the specific gravity of the material at a definite temperature.

This is the standard United States gallon.

Water.—Dissolved water or water not definitely or chemically combined.

Dry.—In paint materials: containing no uncombined water. In paint films: completely solidified.

STANDARD METHODS OF TESTING LUBRICANTS

(SPECIFIC GRAVITY, FREE ACID, CARBON RESIDUE, VISCOSITY).

Serial Designation: D 47 – 21.

These tests are issued under the fixed designation D 47; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted, 1918; Revised, 1921.

SPECIFIC GRAVITY.

Specific Gravity. 1. Specific Gravity may be determined by hydrometer, Westphal balance, or pyknometer, providing these instruments are verified. The observation shall be taken with the sample at 15°.56 C. compared with water of the same temperature. Correction for the bouyant effect of the atmosphere shall be made when necessary.

FREE ACID.

Free Acid. 2. Accurately weigh 10 g. of the oil into a flask, add 50 cc. of 95-per-cent alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with aqueous tenth-normal alkali, free from carbonate, using phenolphthalein, alkali blue or tumeric as an indicator, agitating thoroughly after each addition of alkali.

Express results either as percentage of oleic acid or as acid number (milligrams of potassium hydroxide required to saturate the free acids in 1 g. of fat or oil).

1 cc. of tenth-normal alkali = 0.0282 gram of oleic acid. Alkali, 1 cc. of which is equivalent to 0.00996 g. of KOH, and 1 cc. of which is equivalent to 0.5 per cent of oleic acid, may be used.

Follow the same method for mineral oils excepting the alcohol which should consist of equal proportions of distilled water and 95-per-cent alcohol.

In titrating dark-colored mineral oils, the end reaction is better observed when alkali blue 6 B. is used as the indicator.

CARBON RESIDUE.[1]

(CONRADSON METHOD)

3. The apparatus (see Fig. 1) consists of:

Apparatus.

(*a*) Porcelain crucible, wide form, glazed throughout, 25 to 26-cc. capacity, 46 mm. in diameter.

(*b*) Skidmore iron crucible, 45-cc. (1½ oz.) capacity, 65 mm. in diameter, 37 to 39 mm. high with cover, without delivery tubes and one opening closed.

(*c*) Wrought-iron crucible with cover, about 180 cc. capacity, 80 mm. diameter, 58 to 60 mm. high. At the bottom of this crucible a layer of sand is placed about 10 mm. deep or enough to bring the Skidmore crucible with cover on nearly to the top of the wrought-iron crucible.

(*d*) Triangle, pipe stem covered, projection on side so as to allow flame to reach the crucible on all sides.

(*e*) Sheet iron or asbestos hood provided with a chimney about 2 to 2½ in. high, 2⅛ to 2¼ in. in diameter to distribute the heat uniformly during the process.

(*f*) Asbestos or hollow sheet iron block, 6 to 7 in. square, 1¼ to 1½ in. high, provided with opening in center 3¼ in. in diameter at the bottom, and 3½ in. in diameter at the top.

Procedure.

4. The test shall be conducted as follows:

Ten grams of the oil to be tested are weighed in the porcelain crucible, which is placed in the Skidmore crucible and these two crucibles set in the larger iron crucible, being careful to have the Skidmore crucible set in the center of the iron crucible, covers being applied to the Skidmore and iron crucibles. Place on triangle and suitable stand with asbestos block and cover with sheet iron or asbestos hood in order to distribute the heat uniformly during the process.

Heat from a Bunsen burner or other burner is applied with a high flame surrounding the large crucible, as shown in Fig. 1, until vapors from the oil start to ignite over the crucible, when the heat is slowed down so that the vapor (flame) will come off at a uniform rate. The flame from the ignited vapors should not extend over 2 in. above the sheet iron hood. After the vapor ceases to come off the heat is increased as at the start and kept so for five minutes, making the lower part of large crucible red hot, after which the apparatus is allowed to cool somewhat before uncovering the crucible. The porcelain crucible is removed, cooled in a desiccator and weighed.

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[1] This method is a modification by P. H. Conradson of his original method and apparatus for Carbon Test and Ash Residue in Petroleum Lubricating Oils. See *Proceedings*, Eighth International Congress of Applied Chemistry, New York, September, 1912, Vol. 1, p. 131. Also reprint in the *Journal of Industrial and Engineering Chemistry*, Vol. 4, No. 11, November, 1912.

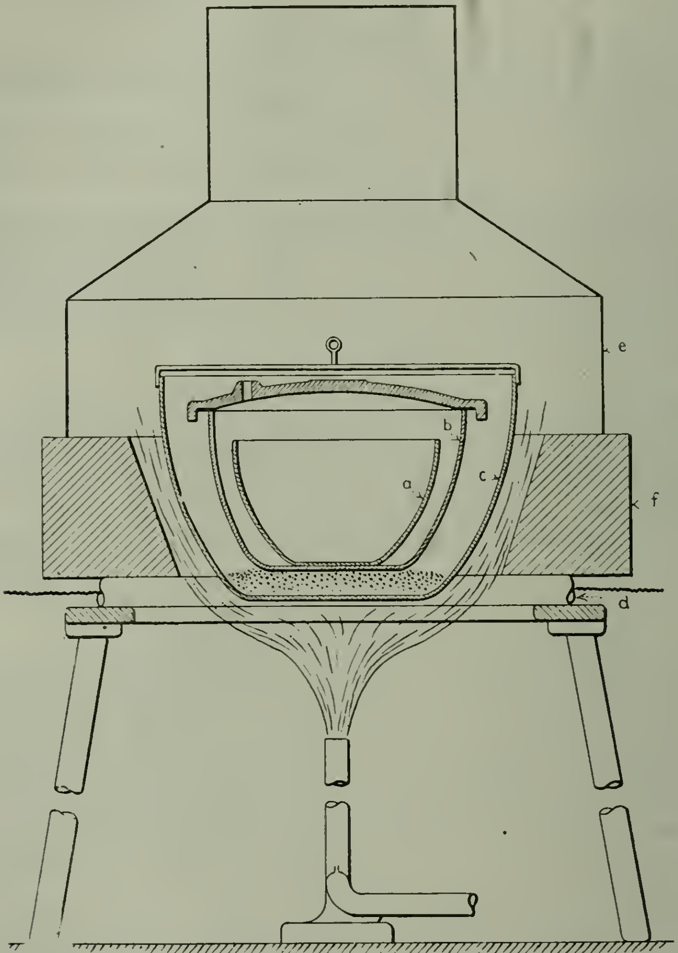

FIG. 1.—Apparatus for Determining Carbon Residue

The entire process should require about one-half hour to complete when heat is properly regulated. The time will depend somewhat upon the kind of oil tested, as a very thin, rather low-flash-point oil will not take as long as a heavy, thick, high-flash-point oil.

VISCOSITY.

Viscosity. 5. Viscosity shall be determined by means of the Saybolt Standard Universal Viscosimeter.

Apparatus. 6. (*a*) The Saybolt Standard Universal Viscosimeter (see Fig. 2) is made entirely of metal. The standard oil tube *A* is fitted at the top with an overflow cup *B*, and the tube is surrounded by a bath. At the bottom of the standard oil tube is a small outlet tube through which the oil to be tested flows into a receiving flask, Fig. 3, whose capacity to a mark on its neck is 60 (±0.15) cc. The lower end of the outlet tube is enclosed by a larger tube, which when stoppered by a cork, *C*, acts as a closed air chamber and prevents the flow of oil through the outlet tube until the cork is removed and the test started. A looped string may be attached to the lower end of the cork as an aid to its rapid removal. The temperatures in the standard oil tube and in the bath are shown by thermometers. The bath may be heated by any suitable means. The standard oil tube shall be thoroughly cleaned, and all oil entering the standard oil tube shall be strained through a 60-mesh wire strainer. A stop watch shall be used for taking the time of flow of the oil and a pipette shall be used for draining the overflow cup of the standard oil tube.

(*b*) The standard oil tube, which may be standardized by the U. S. Bureau of Standards, Washington, D. C., shall conform to the following dimensions:

DIMENSIONS.	MINIMUM, CM.	NORMAL, CM.	MAXIMUM, CM.
Inside diameter of outlet tube..	0.1750	0.1765	0.1780
Length of outlet tube.........	1.215	1.225	1.235
Height of overflow rim above bottom of outlet tube.......	12.40	12.50	12.60
Diameter of container of standard oil tube................	2.955	2.975	2.995
Outer diameter of outlet tube at lower end..................	0.28	0.30	0.32

Procedure. 7. Viscosity shall be determined at 100° F. (37°.8 C.), 130° F. (54°.49 C.), or 210° F. (98°.9 C.). The bath shall be held constant within 0°.25 F. (0°.14 C.) at such a temperature as will maintain the desired temperature in the standard oil tube. For viscosity determinations at 100 and 130° F., oil or water may be used as the bath liquid. For viscosity determinations at

210° F., oil shall be used as the bath liquid. Viscosity determinations shall be made in a room free from draughts, and from rapid changes in temperature. All oil introduced into the standard oil tube, either for cleaning or for test, shall first be passed through the strainer.

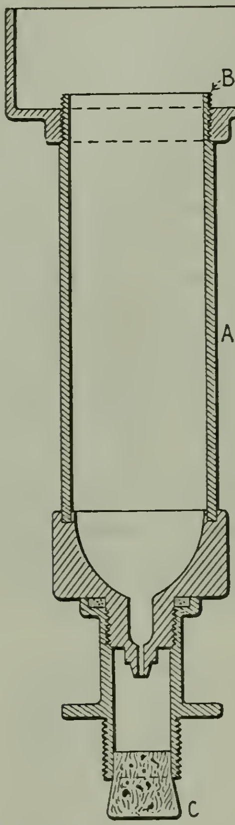

FIG. 2.—Sectional View of Standard Oil Tube.

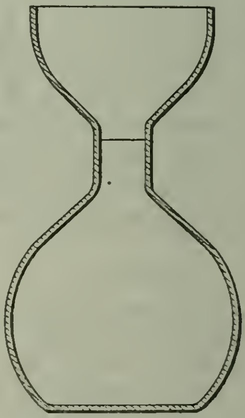

FIG. 3.—Receiving Flask.

To make the test, heat the oil to the necessary temperature and clean out the standard oil tube. Pour some of the oil to be tested through the cleaned tube. Insert the cork stopper into the lower end of the air chamber at the bottom of the standard oil tube, sufficiently to prevent the escape of air, but not to touch the small outlet tube of the standard oil tube.

Heat the oil to be tested, outside the viscosimeter, to slightly below the temperature at which the viscosity is to be determined and pour it into the standard oil tube until it ceases to overflow into the overflow cup. By means of the oil tube thermometer keep the oil in the standard oil tube well stirred and also stir well the oil in the bath. It is extremely important that the temperature of the bath be maintained constant during the entire time consumed in making the test. When the temperature of the bath and of the oil in the standard oil tube are constant and the oil in the standard oil tube is at the desired temperature, withdraw the oil tube thermometer; quickly remove the surplus oil from the overflow cup by means of a pipette so that the level of the oil in the overflow cup is below the level of the oil in the tube proper; place the 60-cc. flask, Fig. 3, in position so that the stream of oil from the outlet tube will strike the neck of the flask so as to avoid foam. Snap the cork from its position, and at the same instant start the stop watch. Stir the liquid in the bath during the run and carefully maintain it at the previously determined proper temperature. Stop the watch when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask.

The time in seconds for the delivery of 60 cc. of oil is the Saybolt Universal viscosity of the oil at the temperature at which the test was made.

STANDARD SPECIFICATIONS
FOR
MATERIALS FOR CEMENT GROUT FILLER FOR BRICK AND STONE BLOCK PAVEMENTS.

Serial Designation: D 57 – 20.

These specifications are issued under the fixed designation D 57; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED, 1920.

I. SAND FOR CEMENT GROUT FILLER.

Sand. 1. The sand shall consist of clean, hard, durable stone particles, preferably siliceous, free from lumps of clay and objectionable foreign matter.

Grading. 2. (*a*) The sand shall be well graded from coarse to fine and when tested by means of laboratory sieves shall meet the following requirements:

		PER CENT.
Total passing 10-mesh sieve		100
Total passing 20-mesh sieve	not less than	80
Total passing 200-mesh sieve	not more than	5

(*b*) This test shall be made in accordance with the Standard Method of Mechanical Analysis of Sand or Other Fine Highway Material, except Fine Aggregates Used in Cement Concrete (Serial Designation: D 7) of the American Society for Testing Materials.

Mortar Strength Test. 3. (*a*) When the sand is mixed with Portland cement passing the requirements of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials, in the proportion of 1 part of cement to 3 parts of sand, by weight, according to the standard method of making 1:3 mortar briquettes, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same consistency, made of 1 part of the same cement and 3 parts of Ottawa sand.

(*b*) Preliminary acceptance samples shall be subjected to both 7 and 28-day mortar tests, and acceptance based thereon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

(*c*) The tests for mortar strength shall be made in accordance with the A.S.T.M. Standard Specifications and Tests for Portland Cement.

NOTE.—The Portland cement used in testing the proposed sand should preferably be that used or to be used in the work.

4. The sand shall be subject to inspection after delivery at the place of use, prior to and during the laying of the pavement. **Inspection.**

5. The sand shall be sampled for testing at the source of supply, if required. Samples shall also be taken for testing from time to time, at the place of use prior to and during the laying of the pavement, whenever desired by the engineer. **Sampling.**

II. PORTLAND CEMENT FOR CEMENT GROUT FILLER.

6. Portland cement for use in cement grout filler shall conform to the requirements of the A.S.T.M. Standard Specifications and Tests for Portland Cement. **Cement.**

III. WATER FOR CEMENT GROUT FILLER.

7. Clean water free from harmful amounts of oil, acid, alkali, organic or vegetable matter shall be used. **Water.**

STANDARD SPECIFICATIONS

FOR

MATERIALS FOR CEMENT MORTAR BED FOR BRICK, STONE BLOCK AND WOOD BLOCK PAVEMENTS.

Serial Designation: D 58 – 20.

These specifications are issued under the fixed designation D 58; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED, 1920.

I. SAND FOR CEMENT MORTAR CUSHION.

Sand. 1. The sand shall consist of clean, hard, durable stone particles, preferably siliceous, free from lumps of clay and any objectionable foreign matter.

Grading. 2. (*a*) The sand shall be well graded from coarse to fine and when tested by means of a laboratory sieve shall meet the following requirement:

Total passing 10-mesh sieve.................... 100 per cent.

(*b*) This test shall be made in accordance with the Standard Method of Mechanical Analysis of Sand or Other Fine Highway Material, except Fine Aggregates Used in Cement Concrete (Serial Designation: D 7) of the American Society for Testing Materials.

Mortar Strength Test. 3. (*a*) When the sand is mixed with Portland cement passing the requirements of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials, in the proportion of 1 part cement to 3 parts of sand, by weight, according to the standard method of making 1:3 mortar briquettes, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same consistency, made of 1 part of the same cement and 3 parts of Ottawa sand.

(*b*) Preliminary acceptance samples shall be subjected to both 7 and 28-day mortar tests, and acceptance based thereon.

Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

(*c*) The tests for mortar strength shall be made in accordance with the A.S.T.M. Standard Specifications and Tests for Portland Cement.

NOTE.—The Portland cement used in testing the proposed sand should preferably be that used or to be used in the work.

Inspection. 4. The sand shall be subject to inspection after delivery at the place of use, prior to and during the laying of the pavement.

Sampling. 5. The sand shall be sampled for testing at the source of supply, if required. Samples shall also be taken for testing from time to time, at the place of use prior to and during the laying of the pavement, whenever desired by the engineer.

II. PORTLAND CEMENT FOR CEMENT MORTAR BED.

Cement. 6. Portland cement for use in the cement mortar cushion shall conform to the requirements of the A.S.T.M. Standard Specifications and Tests for Portland Cement.

STANDARD METHOD OF TEST
FOR
ABRASION OF ROAD MATERIAL.

Serial Designation: D 2 – 08.

This method is issued under the fixed designation D 2; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1908.

This well-known method of test is similar in almost all respects to the Deval abrasion test of the French School of Roads and Bridges. It has been used since 1878, and is entirely satisfactory for the purpose for which it was designed.

Apparatus. 1. The machine shall consist of one or more hollow iron cylinders; closed at one end and furnished with a tightly fitting iron cover at the other; the cylinders to be 20 cm. in diameter and 34 cm. in depth, inside. These cylinders are to be mounted on a shaft at an angle of 30 deg. with the axis of rotation of the shaft.

Preparation of Sample. 2. At least 30 lb. of coarsely broken stone shall be available for a test. The rock to be tested shall be broken in pieces as nearly uniform in size as possible, and as nearly 50 pieces as possible shall constitute a test sample.

Procedure. 3. The total weight of rock in a test shall be within 10 g. of 5 kg. All test pieces shall be washed and thoroughly dried before weighing. Ten thousand revolutions, at a rate of between 30 and 33 per minute, shall constitute a test. Only the percentage of material worn off which will pass through a 0.16-cm. ($\frac{1}{16}$-in.) mesh sieve shall be considered in determining the amount of wear. This may be expressed either as the percentage of the 5 kg. used in the test, or the French coefficient, which is in more general use, may be given; that is, coefficient of wear $= 20 \times \frac{20}{w} = \frac{400}{w}$, where w is the weight in grams of the detritus under 0.16 cm. ($\frac{1}{16}$ in.) in size per kilogram of rock used.

STANDARD METHOD OF TEST
FOR
TOUGHNESS OF ROCK.

Serial Designation: D 3 – 18.

This method is issued under the fixed designation D 3; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1908; Revised, 1918.

This method was approved March 28, 1921, as a "Tentative American Standard" by the American Engineering Sandards Committee.

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1. Toughness, as applied to rock, is the resistance offered to fracture under impact, expressed as the final height of blow required of a standard hammer to cause fracture of a cylindrical test specimen of given dimensions. **Definition.**

2. Any form of impact machine which will comply with the following essentials may be used in making the test: **Impact Machine.**

(*a*) A cast-iron anvil weighing not less than 50 kg., firmly fixed upon a solid foundation;

(*b*) A hammer weighing 2 kg., arranged so as to fall freely between suitable guides;

(*c*) A plunger made of hardened steel and weighing 1 kg., arranged to slide freely in a vertical direction in a sleeve, the lower end of the plunger being spherical in shape with a radius of 1 cm.;

(*d*) Means for raising the hammer and for dropping it upon the plunger from any specified height from 1 to not less than 75 cm., and means for determining the height of fall to approximately 1 mm.;

(*e*) Means for holding the cylindrical test specimen securely on the anvil without rigid lateral support, and under the plunger in such a way that the center of its upper surface shall, throughout the test, be tangent to the spherical end of the plunger at its lowest point.

3. Quarry samples of rock from which test specimens are to be prepared shall measure at least 6 in. on a side and at least 4 in. in thickness, and when possible shall have the plane of structural weakness of the rock plainly marked thereon. **Sampling.**

Samples should be taken from freshly quarried material, and only from pieces which show no evidences of incipient fracture due to blasting or other causes. The samples should preferably be split from large pieces by the use of plugs and feathers and not by sledging. Commercial stone-block samples from which test specimens are to be prepared shall measure at least 3 in. on each edge.

Size and Form of Test Specimens.

4. Specimens for test shall be cylinders prepared as described in Section 5, 25 mm. in height and from 24 to 25 mm. in diameter. Three test specimens shall constitute a test set. The ends of the specimen shall be plane surfaces at right angles to the axis of the cylinder.

Preparation of Test Specimens.

5. One set of specimens shall be drilled perpendicular and another parallel to the plane of structural weakness of the rock, if such plane is apparent. If a plane of structural weakness is not apparent, one set of specimens shall be drilled at random. Specimens shall be drilled in a manner which will not subject the material to undue stresses and which will insure the specified dimensions.[1] The ends of the cylinders may be sawed by means of a band or diamond saw,[2] or in any other way which will not induce incipient fracture, but shall not be chipped or broken off with a hammer. After sawing, the ends of the specimens shall be ground plane with water and carborundum or emery on a cast-iron lap until the cylinders are 25 mm. in length.

Method of Testing.

6. The test shall consist of a 1-cm. fall of the hammer for the first blow, a 2-cm. fall for the second blow, and an increase of 1-cm. fall for each succeeding blow until failure of the test specimen occurs.

Recording and Reporting Results.

7. The height of the blow in centimeter at failures shall be the toughness of the test specimen. The individual and the average toughness of three test specimens shall be reported when no plane of structural weakness is apparent. In cases where a plane of structural weakness is apparent, the individual and average toughness of the three specimens in each set shall be reported and identified. Any peculiar condition of a test specimen which might affect the result, such as the presence of seams, fissures, etc., shall be noted and recorded with the test result.

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[1] The form of diamond drill described in *Bulletin No. 347*, U. S. Department of Agriculture, pp. 6–7, is recommended, and should prove satisfactory if the instructions are strictly followed.

[2] A satisfactory form of diamond saw is described in *Bulletin No. 347*, U. S. Department of Agriculture, pp. 7–9.

STANDARD METHOD OF TEST FOR APPARENT SPECIFIC GRAVITY OF COARSE AGGREGATES.

Serial Designation: D 30 – 18.

This method is issued under the fixed designation D 30; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1916; Adopted, 1918.

The apparent specific gravity shall be determined in the following manner:

1. The sample, weighing 1000 g. and composed of pieces approximately cubical or spherical in shape and retained on a screen having 1.27-cm. ($\frac{1}{2}$-in.) circular openings, shall be dried to constant weight at a temperature between 100 and 110° C. (212 and 230° F.), cooled, and weighed to the nearest 0.5 g. Record this weight as weight A. In the case of homogeneous material, the smallest particles in the sample may be retained on a screen having $1\frac{1}{4}$-in. circular openings.

2. Immerse the sample in water for 24 hours, surface-dry individual pieces with aid of a towel or blotting paper, and weigh. Record this weight as weight B.

3. Place the sample in a wire basket of approximately $\frac{1}{4}$-in. mesh, and about 12.7 cm. (5 in.) square and 10.3 cm. (4 in.) deep, suspend in water[1] from center of scale pan, and weigh. Record the difference between this weight and the weight of the empty basket suspended in water as weight C. (Weight of saturated sample immersed in water.)

4. The apparent specific gravity shall be calculated by dividing the weight of the dry sample (A) by the difference between the weights of the saturated sample in air (B) and in water (C), as follows:

$$\text{Apparent Specific Gravity} = \frac{A}{B-C}.$$

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[1] The basket may be conveniently suspended by means of a fine wire hung from a hook shaped in the form of a question mark with the top end resting on the center of the scale pan.

5. Attention is called to the distinction between apparent specific gravity and true specific gravity. Apparent specific gravity includes the voids in the specimen and is therefore always less than or equal to, but never greater than the true specific gravity of the material.

STANDARD METHODS OF TEST
FOR
APPARENT SPECIFIC GRAVITY OF SAND, STONE AND SLAG SCREENINGS, AND OTHER FINE NON-BITUMINOUS HIGHWAY MATERIALS.

Serial Designation: D 55 – 19.

These methods are issued under the fixed designation D 55; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1918; Adopted, 1919.

Alternate Methods. 1. The following tests, "Le Chatelier" and "Jackson," are equally suited for use in determining the apparent specific gravity of sand, stone and slag screenings and other fine non-bituminous highway materials, and may be considered as alternates:

LE CHATELIER TEST.

Apparatus. 2. The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 1. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baume, shall be used in making this determination.

Method. 3. (*a*) The flask shall be filled with either of these liquids to a point on the stem between zero and one cubic centimeter and 64 g. of sand or other fine non-bituminous highway material of the same temperature as the liquid, shall be slowly introduced, taking care that the material does not adhere to the inside of the flask above the liquid and to free the material from air by rolling the flask in an inclined position. After all material is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 g. of the material.

The specific gravity shall then be calculated from the formula:

$$\text{Specific gravity} = \frac{\text{Weight of material (g.)}}{\text{Displaced volume (cc.)}}$$

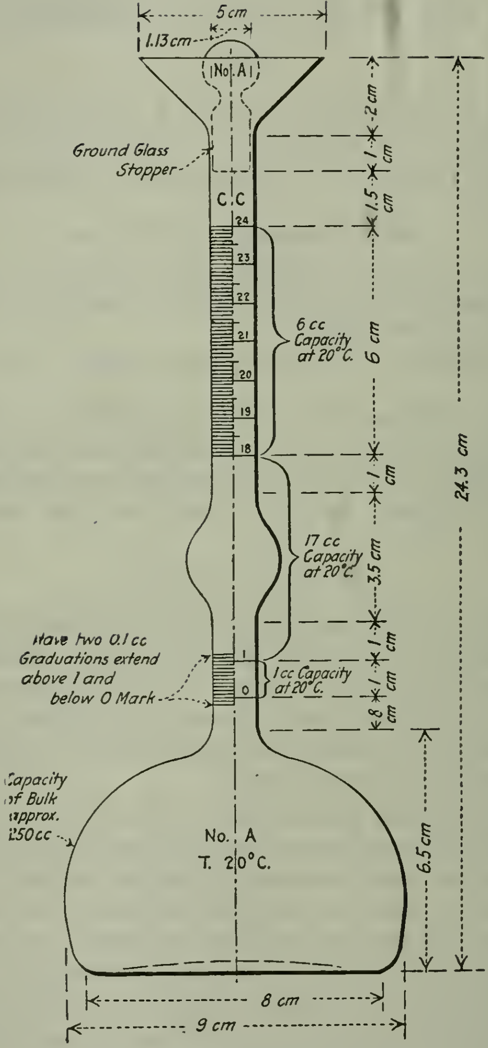

FIG. 1.—Le Chatelier Apparatus.

(*b*) The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0°.5 C. The results of repeated tests should agree within 0.01.

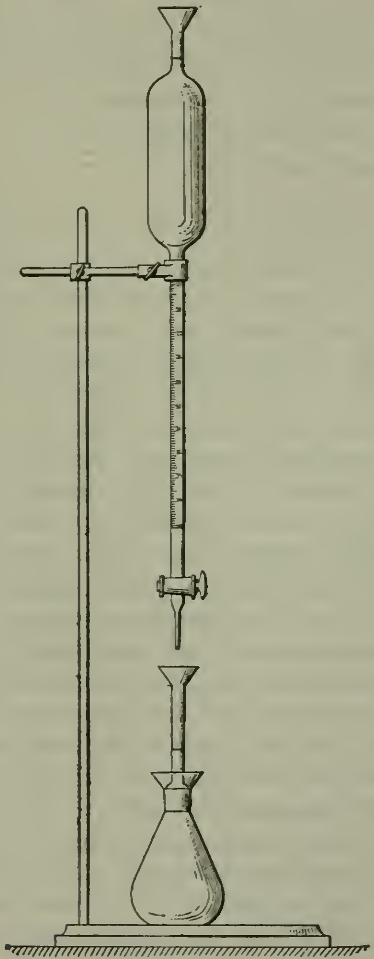

FIG. 2.—Jackson Apparatus.

JACKSON TEST.

4. The determination shall be made with a Jackson specific-gravity apparatus (illustrated in Fig. 2) which shall consist of a burette, with graduations reading to 0.01 in specific gravity, about 23 cm. (9 in.) long and with an inside diameter of about **Apparatus.**

0.6 cm. (0.25 in.), which shall be connected with a glass bulb approximately 13 cm. (5.5 in.) long and 4.5 cm. (1.75 in.) in diameter, the glass bulb being of such size that from a mark on the neck at the top to a mark on the burette just below the bulb, the capacity is exactly 180 cc. (6.09 liquid oz.); and an Erlenmeyer flask, which shall contain a hollow ground-glass stopper having the neck of the same bore as the burette, and shall have a capacity of exactly 200 cc. (6.76 oz.) up to the graduation on the neck of the stopper.

Method. 5. The method is as follows:

(1) Dry at not more than 110° C. (230° F.) to a constant weight a sample weighing about 55 g.; (2) weigh 50 g. of the dry sample to 0.1 g. and pour it into the unstoppered Erlenmeyer flask, which shall be cleaned and dried before each determination; (3) fill the bulb and burette with kerosene, leaving just space enough to take the temperature by introducing a thermometer through the neck; (4) remove the thermometer and add sufficient kerosene to fill exactly to the mark on the neck, drawing off any excess with the burette; (5) run into the flask about one-half of the kerosene in the bulb to remove air bubbles and then run in more kerosene, removing any material adhering to the neck of the flask, until the kerosene is just below the ground glass; (6) place the hollow ground-glass stopper in position and turn it to fit tightly, and then run in kerosene exactly to the200-cc. (6.76-oz.) graduation on the neck, care being taken to remove all air bubbles in the flask; (7) read the specific gravity from the graduation on the burette, and the temperature of the oil in the flask, noting the difference between the temperature of the oil in the bulb before the determination and that of the oil in the flask after the determination; (8) make a temperature correction to the reading of the specific gravity in accordance with the table furnished by the manufacturer of the apparatus, adding the correction if the temperature of the kerosene has increased and subtracting it if the temperature of the kerosene has decreased.

STANDARD METHOD OF TEST
FOR
QUANTITY OF CLAY AND SILT IN GRAVEL FOR HIGHWAY CONSTRUCTION.

Serial Designation: D 72 – 21.

This method is issued under the fixed designation D 72; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1920; Adopted, 1921.

Scope. 1. This test covers the determination of the quantity of clay and silt in natural gravel to be used in highway construction.

Treatment of Sample. 2. The sample as received shall be moistened and thoroughly mixed, then dried to constant weight at a temperature between 100 and 110° C. (212 and 230° F.).

Apparatus. 3. The pan or vessel to be used in the determination shall be 12 in. (30.5 cm.) in diameter by not less than 4 in. (10.2 cm.) deep, as nearly as may be obtained.

Procedure. 4. (*a*) A representative portion of the dry material weighing not less than 50 times the weight of the largest stone in the sample shall be selected from the sample and placed in the pan which has been dried and accurately weighed.

(*b*) Sufficient water shall be poured into the pan to cover the gravel. The gravel shall be agitated vigorously for 15 seconds with a trowel or stirring rod. After it has settled for 15 seconds the water shall be poured off into a tared evaporating dish, care being taken not to pour off any gravel. This is repeated until the wash water is clear. The washed material shall be dried to constant weight in an oven at a temperature between 100 and 110° C. (212 and 230° F.), weighed, and the net weight of gravel determined.

Percentage of Clay. 5. The percentage of clay and silt shall be calculated from the formula:

$$\text{Percentage of Clay and Silt} = \frac{\text{Original weight} - \text{weight after washing}}{\text{Original weight}} \times 100$$

Check Determination. 6. For a check on the results, the wash water shall be evaporated to dryness and the residue weighed:

$$\text{Percentage of Clay and Silt} = \frac{\text{Weight of residue}}{\text{Original weight}} \times 100.$$

STANDARD METHOD OF TEST

FOR

QUANTITY OF CLAY AND SILT IN SAND FOR HIGHWAY CONSTRUCTION.

Serial Designation: D 74 – 21.

This method is issued under the fixed designation D 74; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1920; Adopted, 1921.

Scope. 1. This test covers the determination of the quantity of clay and silt in natural sand to be used in highway construction.

Treatment of Sample. 2. The sample as received shall be moistened and thoroughly mixed, then dried to constant weight at a temperature between 100 and 110° C. (212 and 230° F.).

Apparatus. 3. The pan or vessel to be used in the determination shall be substantially 9 in. (22.9 cm.) in diameter by not less than 4 in. (10.2 cm.) deep. It shall have vertical sides and be provided with a pouring lip.

Procedure. 4. A representative portion of the dry material weighing 500 g., shall be selected from the sample and placed in the pan which has been dried and accurately weighed. Sufficient water shall be poured into the pan to cover the sand (about 225 cc.) and agitated vigorously for 15 seconds. After it has settled for 15 seconds the water shall be poured off into a tared evaporating dish, care being taken not to pour off any sand. This is repeated until the wash water is clear, a glass rod being used to stir the material for the last few washings. The pan and washed sand shall be dried to constant weight in an oven at a temperature between 100 and 110° C. (212 and 230° F.), weighed and the net weight of sand determined.

Percentage of Clay. 5. The percentage of clay and silt shall be calculated from the formula:

$$\text{Percentage of Clay and Silt} = \frac{\text{Original weight} - \text{weight after washing}}{\text{Original weight}} \times 100.$$

Check Determination. 6. For a check on the results, the wash water shall be evaporated to dryness and the residue weighed:

$$\text{Percentage of Clay and Silt} = \frac{\text{Weight of residue}}{\text{Original weight}} \times 100.$$

STANDARD METHOD OF MECHANICAL ANALYSIS
OF
SAND OR OTHER FINE HIGHWAY MATERIAL, EXCEPT FINE AGGREGATES USED IN CEMENT CONCRETE.

Serial Designation: D 7 – 18.

This method is issued under the fixed designation D 7; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1911; Revised, 1916, 1918.

The method shall consist of (1) drying at not over 110° C. (230° F.) to a constant weight a sample weighing 50 g.; (2) passing the sample through each of the mesh sieves (American Society for Testing Materials standard sieves) specified in Table I;[1]

Table I.—A.S.T.M. Standard Sieves.

Mesh Designation.	Unit of Measure.	Actual Mesh.	Opening.	Wire Diameter.	Permissible Variations.	
					Mesh.	Diameter.
10.......	cm in.	3.9 9.9	0.200 0.079	0.056 0.022	± 0.04 ± 0.1	± 0.005 ± 0.002
20.......	cm. in.	8 20.3	0.085 0.0335	0.040 0.0157	± 0.2 ± 0.5	± 0.0015 ± 0.0006
30.......	cm. in.	12.0 30.5	0.050 0.0197	0.033 0.0130	± 0.4 ± 1.0	± 0.0012 ± 0.0005
40.......	cm. in.	16 40.6	0.036 0.0142	0.026 0.0102	± 0.6 ± 1.5	± 0.0010 ± 0.0004
50.......	cm. in.	20 50.8	0.029 0.0114	0.021 0.0083	± 0.8 ± 2	± 0.0010 ± 0.0004
80.......	cm. in.	31 78.7	0.017 0.0067	0.015 0.0059	± 1 ± 3	± 0.0008 ± 0.0003
100.......	cm. in.	39 99.1	0.014 0.0055	0.0116 0.0046	± 1 ± 3	± 0.0008 ± 0.0003
200.......	cm. in.	79 200.7	0.0074 0.0029	0.0053 0.0021	± 3 ± 8	± 0.0005 ± 0.0002

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[1] The order in which the sieves are to be used in the process of sifting is immaterial and shall be left optional; but in reporting results the order in which the sieves have been used shall be stated.

(3) determining the percentage by weight retained on each sieve, the sifting being continued on each sieve until less than 1 per cent of the weight retained on each sieve shall pass through the sieve during the last minute of sifting; and (4) recording the mechanical analysis in the following manner:

Passing 200-mesh sieve................................	......	per cent
Passing 100-mesh sieve and retained on a 200-mesh sieve.....	......	"
Passing 80-mesh sieve and retained on a 100-mesh sieve....	......	"
Passing 50-mesh sieve and retained on an 80-mesh sieve....	......	"
....	......	"
	100.00	"

STANDARD METHOD OF MECHANICAL ANALYSIS
OF
BROKEN STONE OR BROKEN SLAG, EXCEPT AGGREGATES USED IN CEMENT CONCRETE.

Serial Designation: D 18 – 16.

This method is issued under the fixed designation D 18; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1916.

The method shall consist of (1) drying at not over 110° C. (230° F.) to a constant weight a sample weighing in pounds six times the diameter in inches of the largest holes required; (2) passing the sample through such of the following size screens having circular openings as are required or called for by the specifications, screens to be used in the order named: 8.89 cm. (3½ in.), 7.62 cm. (3 in.), 6.35 cm. (2½ in.), 5.08 cm. (2 in.), 3.81 cm. (1½ in.), 3.18 cm. (1¼ in.), 2.54 cm. (1 in.), 1.90 cm. (¾ in.), 1.27 cm. (½ in.), and 0.64 cm. (¼ in.); (3) determining the percentage by weight retained on each screen; and (4) recording the mechanical analysis in the following manner:

Passing 0.64-cm. (¼-in.) screen.......................... ...... per cent

Passing 1.27-cm. (½-in.) screen and retained on a 0.64-cm. (¼-in.) screen.. ...... "

Passing 1.90-cm. (¾-in.) screen and retained on a 1.27-cm. (½-in.) screen.. ...... "

Passing 2.54-cm. (1-in.) screen and retained on a 1.90-cm. (¾-in.) screen.. ...... "

.... "

100.00 "

STANDARD METHOD OF MECHANICAL ANALYSIS
OF
MIXTURES OF SAND OR OTHER FINE MATERIAL WITH BROKEN STONE OR BROKEN SLAG, EXCEPT AGGREGATES USED IN CEMENT CONCRETE.

Serial Designation: D 19 – 16.

This method is issued under the fixed designation D 19; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1916.

The method shall consist of (1) drying at not over 110° C. (230° F.) to a constant weight a sample weighing in pounds six times the diameter in inches of the largest holes required; (2) separating the sample by the use of a screen having circular openings 0.64 cm. (¼ in.) in diameter; (3) examining the portion retained on the screen in accordance with the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, except Aggregates Used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials; (4) examining the portion passing this screen in accordance with the Standard Method of Mechanical Analysis of Sand or Other Fine Highway Material, except Fine Aggregates Used in Cement Concrete (Serial Designation: D 7) of the American Society for Testing Materials; and (5) recording the mechanical analysis in the following manner:

Passing 200-mesh sieve..................................	......	per cent
Passing 100-mesh sieve and retained on a 200-mesh sieve...	......	"
Passing 80-mesh sieve and retained on a 100-mesh sieve...	......	"
....	......	"
Passing 10-mesh sieve and retained on a 20-mesh sieve....	......	"
Passing 0.64-cm. (¼-in.) screen and retained on a 10-mesh sieve...	......	"
Passing 1.27-cm. (½-in.) screen and retained on a 0.64-cm. (¼-in.) screen....................................	......	"
Passing 1.90-cm. (¾-in.) screen and retained on a 1.27-cm. (½-in.) screen....................................	......	"
....	......	"
	100.00	"

STANDARD FORM
OF
SPECIFICATIONS FOR CERTAIN COMMERCIAL GRADES OF BROKEN STONE.

Serial Designation: D 35 – 18.

This form of specifications is issued under the fixed designation D 35; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1916; Adopted, 1918.

The broken stone shall consist of one product of the operation of a stone-crushing and screening plant without recombining or mixing, and shall conform to the following mechanical analysis using laboratory screens:

Passing screen having smallest holes selected	From .. to ..	per cent
Passing screen having next to largest holes selected	From .. to ..	"
Passing screen having largest holes selected	From .. to ..	"
Total passing screen having largest holes selected	100	"

Example.—The broken stone shall consist of one product of the operation of a stone-crushing and screening plant without recombining or mixing, and shall conform to the following mechanical analysis using laboratory screens:

Passing ½-in. screen	3 to 10	per cent
Passing 1-in. screen and retained on ½-in. screen	80 to 95	"
Passing 1½-in. screen and retained on 1-in. screen	2 to 10	"
Total passing 1½-in. screen	100	"

or the analysis may be expressed as follows:

Total passing ½-in. screen	3 to 10	per cent
Total passing 1-in. "	90 to 98	"
Total passing 1½-in. "	100	"

STANDARD METHOD OF TEST
FOR
SOLUBLE BITUMEN.[1]

Serial Designation: D 4-11.

This method is issued under the fixed designation D 4; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1911.

Drying the Sample and Preparing it for Analysis.—It was decided, owing to the great variety of conditions met with in bituminous compounds, that it is impossible to specify any one method of drying that would be satisfactory in every case. It is therefore supposed that the material for analysis has been previously dried either in the laboratory or in the process of refining or manufacture, and that water, if present, exists only as moisture in the hydroscopic form.

The material to be analyzed, if hard and brittle, is ground and spread in a thin layer in a suitable dish (iron or nickel will answer every purpose) and kept at a temperature of 125° C. for one hour. In the case of paving mixtures and road materials, where it is not desirable to crush the rock or sand grains, a lump may be placed in the drying oven until it is thoroughly heated through, when it can be crushed down into a thin layer and dried as above. If the material under examination contains any hydrocarbons at all volatile at this temperature, it will of course be necessary to resort to other means of drying. Tar or oils may be dehydrated by distillation and the water-free distillate returned to the residue and thoroughly incorporated with it.

Analysis of Sample.—After drying, from 2 to 15 g. (as may be necessary to insure the presence of 1 to 2 g. of pure bitumen) is weighed into a 150-cc. tared Erlenmeyer flask, and treated with 100 cc. of carbon disulfide. The flask is then loosely corked and shaken from time to time until all large particles of the material have been broken up. It is then set aside for 48 hours to settle. The solution is decanted into a similar flask that has been previously weighed. As much of the solvent is poured off as possible without disturbing the residue. The contents of the first flask are again treated with fresh carbon disulfide, shaken as before, and then put away with the second flask for 48 hours to settle.

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[1] Committee D-4 on Road Materials, by whom this Standard Method was prepared, wishes it understood that it does not recommend it as the best for general use, as it is longer and in many cases gives no better results than other more expeditious methods, but only as a test to be resorted to in case of dispute, as it seems to have the widest range of applicability of any of the tests considered. Moreover, it wishes it to be understood that with some classes of materials the method will show a lower percentage of soluble bitumen than many of the shorter methods.

The liquid in the second flask is then carefully decanted upon a weighed Gooch crucible, 3.2 cm. in diameter at the bottom, fitted with an asbestos filter, and the contents of the first flask are similarly treated. The asbestos filter is made of ignited long-fiber amphibole, packed in the bottom of a Gooch crucible to the depth of not over ⅛ in. In filtering no vacuum is to be used and the temperature is to be kept between 20 and 25° C. After passing the liquid contents of both flasks through the filter, the residue on the filter is thoroughly washed and the residues remaining in them are shaken with more fresh carbon disulfide and allowed to settle for 24 hours, or until it is seen that a good subsidation has taken place. The solvent in both flasks is then again decanted through the filter and the residues remaining in them are washed until the washings are practically colorless. All washings are to be passed through the Gooch crucible.

The crucible and both flasks are then dried at 125° C. and weighed. The filtrate containing the bitumen is evaporated, the bituminous residue burned, and the weight of the ash thus obtained added to that of the residue in the two flasks and the crucible. The sum of these weights deducted from the weight of substance taken gives the weight of soluble bitumen.

STANDARD METHOD OF TEST
FOR
PENETRATION OF BITUMINOUS MATERIALS.

Serial Designation: D 5 – 21.

This method is issued under the fixed designation D 5; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1911; Revised, 1916, 1921.

I. DEFINITION.

Definition of Penetration. 1. Penetration is defined as the consistency of a bituminous material, expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time and temperature. Where the conditions of test are not specifically mentioned, the load, time and temperature are understood to be 100 g., 5 seconds, 25° C. (77° F.), respectively, and the units of penetration to indicate hundredths of a centimeter.

II. APPARATUS.

Container. 2. The container for holding the material to be tested shall be a flat-bottom, cylindrical dish, 55 mm. ($2\frac{3}{16}$ in.) in diameter and 35 mm. ($1\frac{3}{8}$ in.) deep.[1]

Needle. 3. The needle (Fig. 1) for this test shall be a cylindrical steel rod 50.8 mm. (2 in.) long, having a diameter of 1.01 to 1.02 mm. and having a taper of 6.34 to 6.36 mm. measured on the axis. After tapering, the point shall be "blunted" by grinding off to a truncated cone, the smaller base of which shall be from 0.14 to 0.16 mm. in diameter.

Water Bath. 4. The water bath shall be maintained at a temperature not varying more than 0°.1 C. from 25° C. (77° F.). The volume of water shall be not less than 10 liters and the sample shall be immersed to a depth of not less than 10 cm. (4 in.) and shall be supported on a perforated shelf not less than 5 cm. (2 in.) from the bottom of the bath.

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[1] This requirement is fulfilled by the American Can Company's Gill style ointment box, deep pattern, 3 oz. capacity.

Apparatus for Penetration.

5. Any apparatus which will allow the needle to penetrate without appreciable friction, and which is accurately calibrated to yield results in accordance with the definition of penetration, will be acceptable.

Transfer Dish for Container.

6. The transfer dish for container shall be a small dish or tray of such capacity as will insure complete immersion of the container during the test. It shall be provided with some means which will insure a firm bearing and prevent rocking of the container.

III. PREPARATION OF SAMPLE.

Preparation of Sample.

7. The sample shall be completely melted at the lowest possible temperature and stirred thoroughly until it is homogeneous and free from air bubbles. It shall then be poured into the sample container to a depth of not less than 15 mm. ($\frac{5}{8}$ in.). The sample shall be protected from dust and allowed to cool in an atmosphere not lower than 18° C. (65° F.) for one hour. It shall then be placed in the water bath along with the transfer dish and allowed to remain one hour.

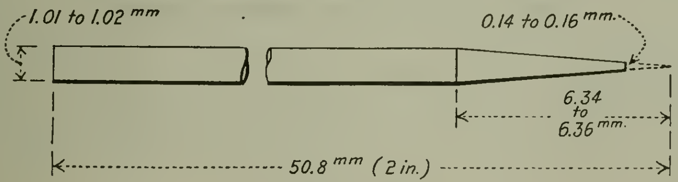


FIG. 1.—Needle for Penetration Test.

IV. PROCEDURE.

Procedure.

8. (*a*) In making the test the sample shall be placed in the transfer dish filled with water from the water bath of sufficient depth to completely cover the container. The transfer dish containing the sample shall then be placed upon the stand of the penetration machine. The needle loaded with specified weight, shall be adjusted to make contact with the surface of the sample. This may be accomplished by making contact of the actual needle point with its image reflected by the surface of the sample from a properly placed source of light. Either the reading of the dial shall then be noted or the needle brought to zero. The needle is then released for the specified period of time, after which the penetration machine is adjusted to measure the distance penetrated.

At least three tests shall be made at points on the surface of the sample not less than 1 cm. ($\frac{3}{8}$ in.) from the side of the container and not less than 1 cm. ($\frac{3}{8}$ in.) apart. After each test the sample and transfer dish shall be returned to the water bath and the needle shall be carefully wiped toward its point with a clean, dry cloth to remove all adhering bitumen. The reported penetration shall be the average of at least three tests whose values shall not differ more than four points between maximum and minimum.

(*b*) When desirable to vary the temperature, time and weight, and, in order to provide for a uniform method of reporting results when variations are made, the samples shall be melted and cooled in air as above directed. They shall then be immersed in water or brine, as the case may require, for one hour at the temperature desired. The following combinations are suggested:

At 0° C. (32° F.) 200-g. weight, 60 seconds.
At 46°.1 C. (115° F.) 50-g. weight, 5 seconds.

STANDARD METHOD OF TEST
FOR
LOSS ON HEATING OF OIL AND ASPHALTIC COMPOUNDS.

Serial Designation: D 6 – 20.

This method is issued under the fixed designation D 6; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1911; Revised, 1916, 1920.

1. This test is used to determine the loss in weight (exclusive of water) of oil and asphaltic compounds when heated as hereinafter prescribed. The material under examination must therefore first be tested for water and if water is found to be present, it must be removed by suitable methods of dehydration before the material is subjected to the loss on heating test; or another sample obtained which is free from water.

I. APPARATUS.

Oven.

2. The oven may be either circular or rectangular in form and may be heated by either gas or electricity. Its interior dimensions shall be as follows: height, not less than 40.64 cm. (16 in.); width and depth or diameter, at least 4.08 cm. (2 in.) greater than the diameter of the revolving shelf.

It shall be well ventilated and shall be fitted with a window in the upper half of the door, so placed and of sufficient size to permit the accurate reading of the thermometer without opening the door. It shall also be provided with a perforated circular shelf preferably of approximately 24.8 cm. (9.75 in.) in diameter. This shelf shall be placed in the center of the oven and shall be suspended by a vertical shaft and provided with mechanical means for rotating it at the rate of 5 to 6 revolutions per minute. It shall be provided with recesses equidistant from the central shaft in which the tins containing the samples are to be placed. (A recommended form of aluminum shelf is shown in Fig. 1).

Thermometer.

3. The thermometer shall be between 12.7 cm. (5 in.) and 15.24 cm. (6 in.) in length and the mercury bulb shall be

from 10 to 15 mm. (0.39 to 0.59 in.) in length. The scale shall be engraved on the stem, shall be clear cut and distinct, and shall run from 150 to 175° C. (302 to 347° F.) in 1° C. divisions and shall commence substantially 3.81 cm. (1½ in.) above the top of the bulb. Every fifth graduation shall be larger than the intermediate ones and shall be numbered. The degrees shall be substantially 3.17 mm. (⅛ in.) apart. The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and be so annealed as to not change its readings under conditions of use. It shall be correct to 0°.25 C. (0°.45 F.) as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the United States Bureau of Standards.

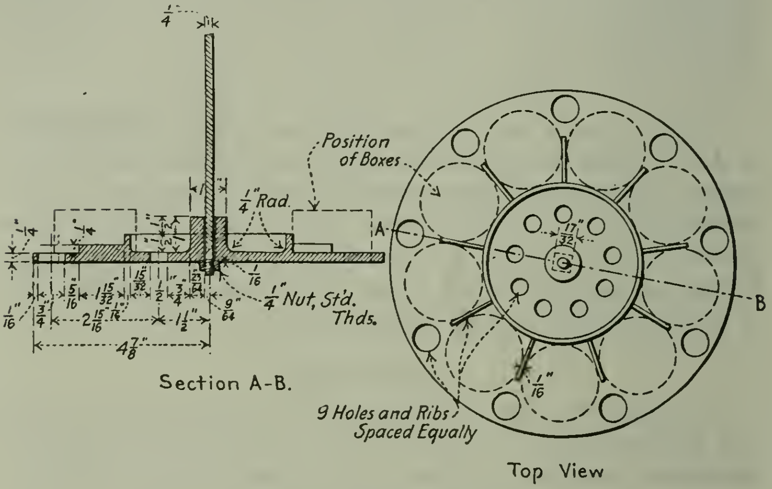


FIG. 1.—Aluminum Shelf.

Container. 4. The container in which the sample is to be tested shall be of tin, cylindrical in shape, and shall have a flat bottom. Its inside dimensions shall be substantially as follows: diameter, 55 mm. (2.17 in.); depth, 35 mm. (1.38 in.). (A 3-oz. Gill style ointment box, deep pattern, fulfills these requirements.)

II. PREPARATION OF SAMPLE.

Preparation of Sample. 5. The sample as received shall be thoroughly stirred and agitated, warming, if necessary, to insure a complete mixture before the portion for analysis is removed.

III. PROCEDURE.

Procedure.

6. Weigh 50 g. of the water-free material to be tested into a tared container conforming to the requirements of Section 4. Bring the oven to a temperature of 163° C. (325° F.), and place the tin box containing the sample in one of the recesses of the revolving shelf. The thermometer shall be immersed for the depth of its bulb in a separate 50-g. sample of the material under test, placed in a similar container, and shall be conveniently suspended from the vertical shaft. This sample shall rest in one of the recesses upon the same shelf and revolve with the sample or samples under test. Then close the oven and rotate the shelf 5 to 6 revolutions per minute during the entire test. Maintain the temperature at 163° C. (325° F.) for 5 hours, then remove the sample from the oven, cool and weigh, and calculate the loss due to volatilization.

Permissible Variation in Temperature.

7. During the 5-hour period the temperature shall not vary more than 1° C. All tests showing a greater variation in temperature shall be rejected.

Precautions.

8. Under ordinary circumstances a number of samples having about the same degree of volatility may be tested at the same time. Samples varying greatly in volatility should be tested separately. Where extreme accuracy is required not more than one material should be tested at one time and duplicate samples of it should be placed simultaneously in the oven. Such duplicates shall check within the limits of accuracy given above. Results obtained on samples showing evidences of foaming during the test shall be rejected.

IV. ACCURACY.

Accuracy.

9. Up to 5 per cent loss in weight the results obtained may be considered as correct within 0.5. Above 5 per cent. loss in weight the numerical limit of error increases 0.01 for every 0.5 per cent increase in loss by volatilization as follows:

VOLATILIZATION LOSS, PER CENT.	NUMERICAL CORRECTION.	TRUE VOLATILIZATION LOSS, PER CENT.
5.0	±0.50	4.50 to 5.50
5.5	±0.51	4.91 " 6.01
6.0	±0.52	5.48 " 6.52
10.0	±0.60	9.40 " 10.60
15.0	±0.70	14.30 " 15.70
25.0	±0.90	24.10 " 25.90
40.0	±1.20	38.80 " 41.20

NOTE.

If additional periods of heating are desired, it is recommended that they be made in successive increments of 5 hours each.

When the penetration of the sample after heating is required, melt the residue in the container at the lowest possible temperature and thoroughly mix by stirring, taking care to avoid incorporating air bubbles in the mass. Then bring it to the standard temperature and test as prescribed under the directions for the Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5) of the American Society for Testing Materials.

STANDARD METHOD OF TEST

FOR

DISTILLATION OF BITUMINOUS MATERIALS SUITABLE FOR ROAD TREATMENT.

Serial Designation: D 20 – 18.

This method is issued under the fixed designation D 20; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1916; Revised, 1918.

This method was approved March 28, 1921,
as "Tentative American Standard" by the
American Engineering Standards Committee.

Sampling. 1. The sample as received shall be thoroughly stirred and agitated, warming, if necessary, to insure a complete mixture before the portion for analysis is removed.

Dehydration. 2. If the presence of water is suspected or known, the material shall be dehydrated before distillation. About 500 cc. of the material are placed in an 800-cc. copper still provided with a distilling head connected with a water-cooled condenser. A ring burner is used, starting with a small flame at the top of the still, and gradually lowering it, if necessary, until all the water has been driven off. The distillate is collected in a 200-cc. separatory funnel with the tube cut off close to the stopcock. When all the water has been driven over and the distillate has settled out, the water is drawn off and the oils returned to the residue in the still. The contents of the still shall have cooled to below 100° C. before the oils are returned, and they shall be well stirred and mixed with the residue.

Apparatus. 3. The apparatus shall consist of the following standard parts:

(*a*) *Flask.*—The distillation flask shall be a 250-cc. Engler distilling flask, having the following dimensions:

Diameter of bulb	8.0 cm.
Length of neck	15.0 cm.
Diameter of neck	1.7 cm.
Surface of material to lower side of tubulature	11.0 cm.
Length of tubulature	15.0 cm.
Diameter of tubulature	0.9 cm.
Angle of tubulature	75 deg.

A variation of 3 per cent from the above measurements will be allowed.

(*b*) *Thermometer.*—The thermometer shall conform to the following requirements:

It shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number, and the letters "A.S.T.M. Distillation."

The thermometer shall be graduated from 0 to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear-cut and distinct.

The thermometer shall conform to the following dimensions:

Total length, maximum	385 mm.	
Diameter of stem	7 "	; permissible variation, 0.5 mm.
Diameter of bulb, minimum	5 "	; and shall not exceed diameter of stem.
Length of bulb	12.5 "	permissible variation, 2.5 mm.
Distance from 0° to bottom of bulb	30 "	; " " 5.0 "
Distance from 0° to 400°	295 "	; " " 10 "

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error from 0 to 200° C. shall not exceed the following:

From 0 to 200° C.	0°.5 C.
" 200 " 300° C.	1°.0 C.
" 300 " 375° C.	1°.5 C.

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water at the barometric pressure, at the time of test, and plunged into free flow of steam, the meniscus shall pass the point 10° C. below the boiling point of water in not more than 6 seconds.

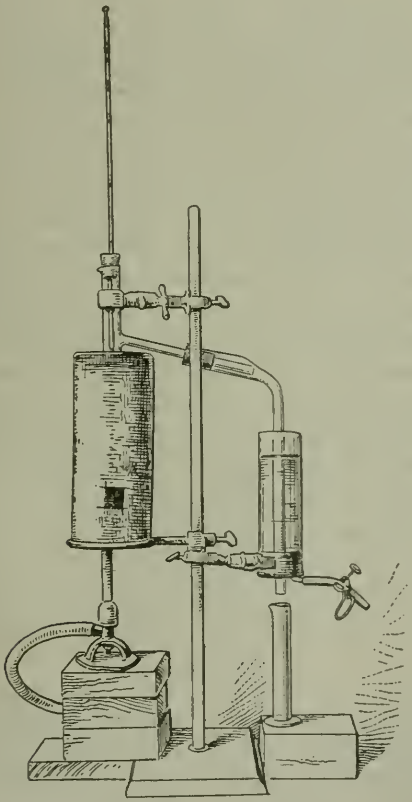


FIG. 1.—Apparatus for Determination of Distillation

The thermometer shall be set up as for the distillation test, using water, naphthalene and benzophenone as distilling liquids. The correctness of the thermometer shall be checked at 0 and 100° C. after each third distillation until seasoned.

(*c*) *Condenser.*—The condenser tube shall have the following dimensions:

Adapter	70	mm.
Length of straight tube	185	"
Width of tube	12–15	"
Width of adapter end of tube	20–25	"

(*d*) *Stands.*—Two iron stands shall be provided, one with a universal clamp for holding the condenser, and one with a light grip arm with a cork-lined clamp for holding the flask.

(*e*) *Burner and Shield.*—A Bunsen burner shall be provided, with a tin shield 20 cm. long by 9 cm. in diameter. The shield shall have a small hole for observing the flame.

(*f*) *Cylinders.*—The cylinders used in collecting the distillate shall have a capacity of 25 cc., and shall be graduated in 0.1 cc.

Setting up the Apparatus.

4. The apparatus shall be set up as shown in Fig. 1, the thermometer being placed so that the top of the bulb is opposite the middle of the tubulature. All connections should be tight.

Procedure.

5. One hundred cubic centimeters of the dehydrated material to be tested shall be placed in a tared flask and weighed. After adjusting the thermometer, shield, condenser, etc., the distillation is commenced, the rate being so regulated that 1 cc. passes over every minute. The receiver is changed as the mercury column just passes the fractionating point.

The following fractions should be reported:

Start of distillation to 110° C.
110 to 170° C.
170 to 235° C.
235 to 270° C.
270 to 300° C.
Residue

To determine the amount of residue, the flask is weighed again when distillation is complete. During the distillation the condenser tube shall be warmed when necessary to prevent the deposition of any sublimate. The percentages of fractions should be reported both by weight and by volume.

STANDARD METHOD OF TEST

FOR

SOFTENING POINT OF BITUMINOUS MATERIALS OTHER THAN TAR PRODUCTS.

(RING-AND-BALL METHOD.)

Serial Designation: D 36 – 21.

This method is issued under the fixed designation D 36; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1916; ADOPTED IN AMENDED FORM, 1919; REVISED, 1921.

1. The softening of bituminous materials generally takes place at no definite moment or temperature. As the temperature rises, they gradually and imperceptibly change from a brittle or exceedingly thick and slow flowing material to a softer and less viscous liquid. For this reason the determination of the softening point must be made by a fixed, arbitrary and closely defined method if the results obtained are to be comparable.

I. APPARATUS.

2. The apparatus shall consist of the following:

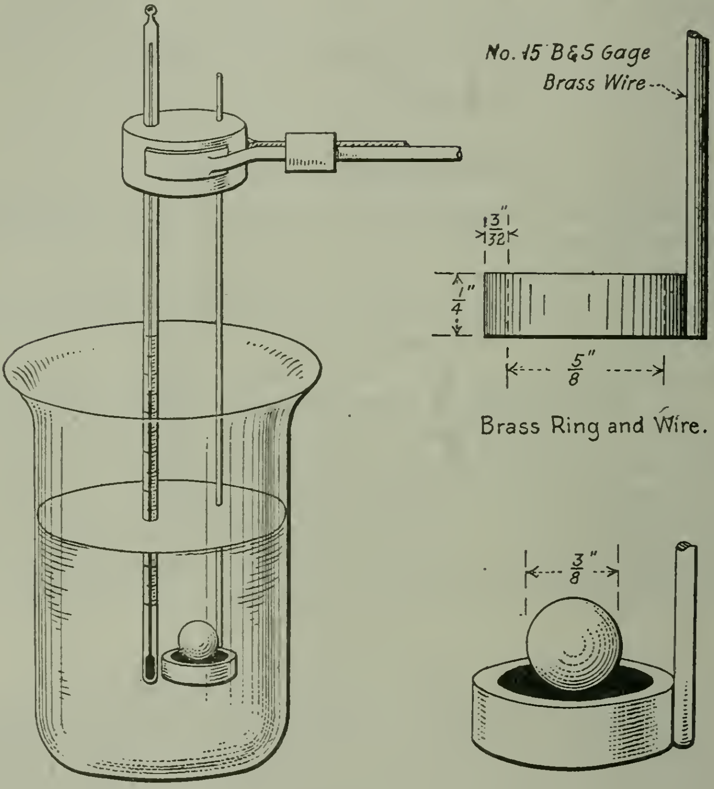
(*a*) A brass ring 15.875 mm. ($\frac{5}{8}$ in.) in inside diameter and 6.35 mm. ($\frac{1}{4}$ in.) deep; thickness of wall, 2.38 mm. ($\frac{3}{32}$ in.); permissible variation on inside diameter and thickness of ring, 0.25 mm. (0.01 in.). This ring shall be attached in a convenient manner to a No. 15 B. & S. gage brass wire (diameter 1.79 mm. = 0.0703 in.). See Fig. 1. **Ring.**

(*b*) A steel ball 9.53 mm. ($\frac{3}{8}$ in.) in diameter weighing between 3.45 and 3.55 g. **Ball.**

(*c*) A glass vessel, capable of being heated, not less than 8.5 cm. (3.34 in.) in diameter and measuring 10.5 cm. (4.13 in.) in depth from the bottom of the flare. (A 600-cc. beaker, low form, meets this requirement.) **Container.**

Thermometer. (*d*) A thermometer which shall conform to the following specifications:

Total length	370 – 400	mm.	(14.57 – 15.75 in.)
Diameter	6.5 – 7.5	"	(0.256 – 0.295 ")
Bulb length	Not over 14	"	(Not over 0.55 ")
Bulb diameter	4.5 – 5.5	"	(0.177 – 0.217 ")



Brass Ring and Wire.

Assembly of Apparatus.

Proper Position of Ball.

FIG. 1.—Apparatus for Ring-and-Ball Method.

The scale shall be engraved upon the stem of the thermometer, shall be clear cut and distinct, and shall run from 0 to 80° C. (32 to 176° F.) in $\frac{1}{5}$° C. divisions. It shall commence not less than 7.5 cm. (2.95 in.) above the bottom of the bulb. The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and be so annealed as not to change its readings under conditions of use. It shall be correct to 0°.25 C. (0°.45 F.) as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the United States Bureau of Standards.

II. PREPARATION OF SAMPLE.

Preparation of Sample. 3. The sample shall be melted and stirred thoroughly, avoiding incorporating air bubbles in the mass, and then poured into the ring so as to leave an excess on cooling. The ring, while being filled, should rest on a brass plate which has been amalgamated to prevent the bituminous material from adhering to it. After cooling, the excess material shall be cut off cleanly with a slightly heated knife.

III. PROCEDURE.

(A) Bituminous Materials having Softening Points 80° C. (176° F.) or below.

Assembling. 4. Assemble the apparatus as shown in Fig. 1. Fill the glass vessel to a depth of substantially 8.25 cm. (3.25 in.) with freshly boiled, distilled water at 5° C. (41° F.). Place the ball in the center of the upper surface of the bitumen in the ring and suspend it in the water so that the lower surface of the filled ring is exactly 2.54 cm. (1 in.) above the bottom of the glass vessel and its upper surface is 5.08 cm. (2 in.) below the surface of the water. Allow it to remain in the water for 15 minutes before applying heat. Suspend the thermometer so that the bottom of the bulb is level with the bottom of the ring and within 0.635 cm. ($\frac{1}{4}$ in.), but not touching, the ring.

Heating. 5. Apply the heat in such a manner that the temperature of the water is raised 5° C. (9° F.) each minute.

Softening Point. 6. The temperature recorded by the thermometer at the instant the bituminous material touches the bottom of the glass vessel shall be reported as the softening point.

Permissible Variation in Rise of Temperature. 7. The rate of rise of temperature shall be uniform and shall not be averaged over the period of the test. The maximum permissible variation for any minute period after the first three shall be ±0°.5 C. (0°.9 F.). All tests in which the rate of rise in temperature exceeds these limits shall be rejected.

(*B*) *Bituminous Materials having Softening Points above 80° C. (176° F.).*

Modifications for Hard Materials.

8. Use the same method as given under (*A*), except that glycerin shall be used instead of water, and that the thermometer shall conform to the following specifications:

Total length	370–400 mm. (14.57 – 15.75 in.)
Diameter of stem	6.5–7.5 mm. (0.256 – 0.295 in.)
Bulb length, not over	14 mm. (0.55 in.)
Bulb diameter	4.5 – 5.5 mm. (0.177 – 0.217 in.)

The graduations shall be from 30 to 160° C. in 0°.5 C. and shall be clear cut and distinct. The 30° mark shall be at least 75 mm. above the bottom of the bulb. The length between the 30° mark and the 160° mark shall be between 230 and 275 mm.

The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and so annealed as not to change its readings under conditions of use. It shall be correct to 0°.25 C. as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the Bureau of Standards.

IV. PRECAUTIONS.

Precautions.

9. The use of freshly boiled distilled water is essential, as otherwise air bubbles may form on the specimen and affect the accuracy of the results. Rigid adherence to the prescribed rate of heating is absolutely essential in order to secure accuracy of results.

A sheet of paper placed on the bottom of the glass vessel and conveniently weighted will prevent the bituminous material from sticking to the glass vessel, thereby saving considerable time and trouble in cleaning.

V. ACCURACY.

Accuracy.

10. The limit of accuracy of the test is ±0°.5 C. (0°.9 F.)

STANDARD METHOD OF TEST

FOR

SOFTENING POINT OF TAR PRODUCTS.

(CUBE-IN-WATER METHOD.)

Serial Designation: D 61 – 20.

This method is issued under the fixed designation D 61; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1919; Adopted in Amended Form, 1920.

1. (*a*) The softening of pitch takes place at no definite moment or temperature. As the temperature rises, pitch gradually and imperceptibly changes from a brittle or exceedingly thick and slow flowing material to a softer and less viscous liquid. For this reason the determination of the softening point must be made by a fixed, arbitrary and closely defined method if the results obtained are to be comparable.

(*b*) The methods herein described are not applicable to pitches having a melting point above 77° C. (170°.6 F.)

(*c*) For the purpose of shortening the time required for testing, hard pitches having a softening point between 43 and 77° C. (109.4 and 170°.6 F.) are cooled at 15°.5 C. (60° F.) instead of at 4° C. (39°.2 F.) as prescribed for soft pitches.

I. APPARATUS.

2. The apparatus shall consist of the following:

Mold. (*a*) A mold suitable for forming a 12.7-mm. ($\frac{1}{2}$-in.) cube of pitch. (A recommended type is shown in Fig. 1.)

Hook. (*b*) An L-shaped right angled hook made of No. 12 B. & S. gage copper wire (diameter 2.05 mm. = 0.0808 in.) the foot of which shall be 2.54 cm. (1 in.) long. See Fig. 1.

Container. (*c*) A glass vessel, capable of being heated, not less than 8.5 cm. (3.34 in.) in diameter and measuring 10.5 cm. (4.13 in.) in depth from the bottom of the flare. (A 600-cc. beaker, Griffin low form, meets this requirement.)

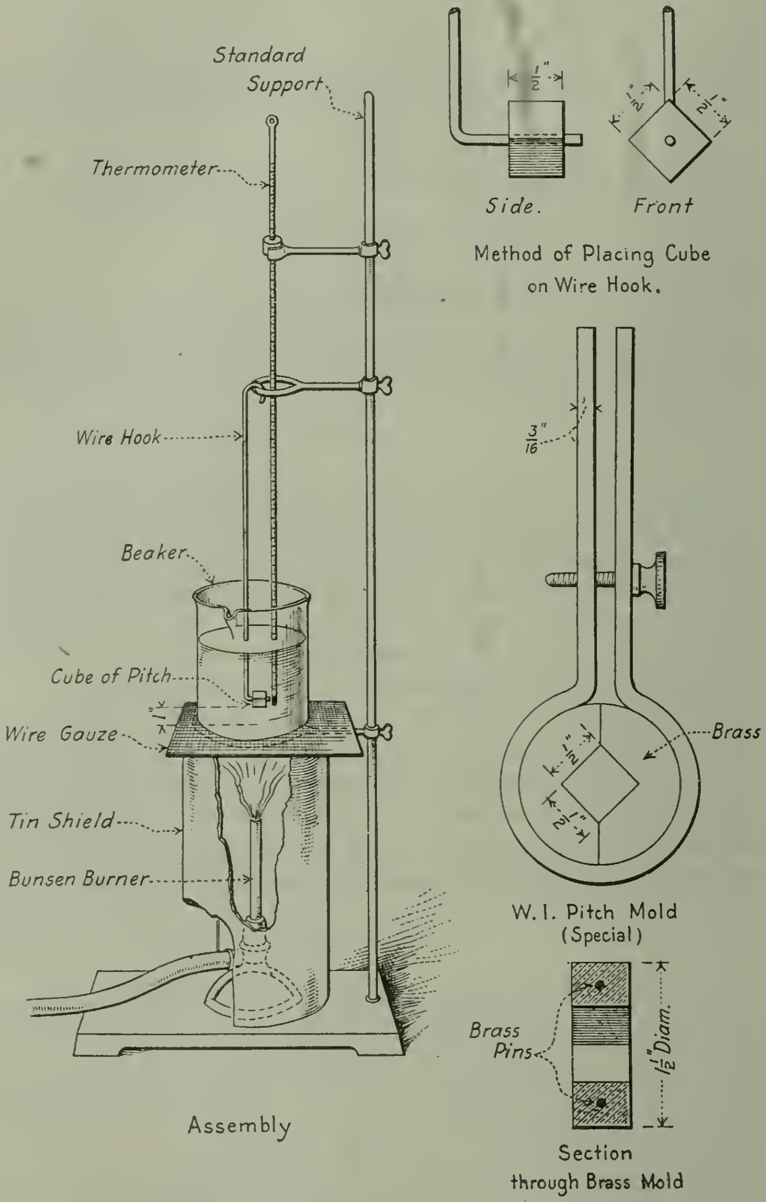


FIG. 1.—Apparatus for Cube-in-Water Method.

Thermometer.

(*d*) A thermometer which shall conform to the following specifications:

Total length	370 – 400	mm.	(14.57 – 15.75 in.)
Diameter	6.5 – 7.5	"	(0.256 – 0.295 ")
Bulb length	Not over 14	"	(Not over 0.55 ")
Bulb diameter	4.5 – 5.5	"	(0.177 – 0.217 ")

The scale shall be engraved upon the stem of the thermometer, shall be clear cut and distinct, and shall run from 0 to 80° C. (32 to 176° F.) in ⅕° C. divisions. It shall commence not less than 7.5 cm. (2.95 in.) above the bottom of the bulb. The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and be so annealed as not to change its readings under conditions of use. It shall be correct to 0°.25 C. (0°.45 F.) as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the United States Bureau of Standards.

II. PREPARATION OF SAMPLE.

Preparation of Sample.

3. The pitch shall be formed into a 12.7-mm. (½-in.) cube, truly shaped and with sharp edges, either by melting and pouring, or softening and pressing, into a mold. In all cases an excess of pitch shall be used and the surplus material shall be cut off cleanly with a slightly heated knife. The harder pitches specified can ordinarily be molded at room temperature, the softer pitches in water at about 4° C. (39°.2 F.) If they are melted, they should first be thoroughly stirred, avoiding incorporating air bubbles in the mass, and then poured into the mold so as to leave an excess on cooling. The mold should rest on a brass plate and the surface of the plate and the interior surfaces of the mold should be amalgamated to prevent the pitch from adhering to them.

III. PROCEDURE.

(*A*) *Pitches having Softening Points between 43 and 77° C. (109.4 and 170°.6 F.).*

Assembling.

4. Assemble the apparatus as shown in Fig. 1. Fill the glass vessel to a depth of substantially 9.5 cm. (3.75 in.) with freshly boiled, distilled water at 15°.5 C. (60° F.). Place the cube of pitch on the wire as shown in Fig. 1 and suspend it in the water so that its lower edge is exactly 2.54 cm. (1 in.) above the bottom of the glass vessel and its upper edge is 5.08 cm.

(2 in.) below the surface of the water. Allow it to remain in the water for 15 minutes before applying heat. Suspend the thermometer so that the bottom of the bulb is level with the bottom edge of the cube of pitch and within 0.635 cm. (¼ in.), but not touching, the cube.

Heating.

5. Apply the heat in such a manner that the temperature of the water is raised 5° C. (9° F.) each minute.

Softening Point.

6. The temperature recorded by the thermometer at the instant the pitch touches the bottom of the glass vessel shall be reported as the softening point.

Permissible Variation in Rise of Temperature.

7. The rate of rise of temperature shall be uniform and shall not be averaged over the period of the test. The maximum permissible variation for any minute period after the first three shall be ±0°.5 C. (0°.9 F.). All tests in which the rate of rise in temperature exceeds these limits shall be rejected.

(*B*) *Pitches having Softening Points below 43° C. (109°.4 F.).*

Modification for Soft Pitches.

8. Use the same method as given under (*A*), except that the water when placed in the glass vessel shall be at a temperature of 4° C. (39°.2 F.). The cube shall be allowed to remain 15 minutes in this water before applying the heat.

IV. PRECAUTIONS.

Precautions.

9. The use of freshly distilled water is essential, as otherwise air bubbles may form on the cube and retard its sinking. Rigid adherence to the prescribed rate of heating is absolutely essential in order to secure accuracy of results.

A sheet of paper placed on the bottom of the glass vessel and conveniently weighted will prevent the pitch from sticking to the glass vessel, thereby saving considerable time and trouble in cleaning.

V. ACCURACY.

Accuracy.

10. The limit of accuracy of the test is ±0°.5 C. (0°.9 F.).

STANDARD DEFINITIONS

OF

TERMS RELATING TO MATERIALS FOR ROADS AND PAVEMENTS.

Serial Designation: D 8-18.

These definitions are issued under the fixed designation D 8; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1915, 1918.

I. BITUMINOUS MATERIALS.

Relating in General to Bituminous Materials:

Bitumens.—Mixtures of native or pyrogenous hydrocarbons and their non-metallic derivatives, which may be gases, liquids, viscous liquids, or solids, and which are soluble in carbon disulfide.

Bituminous.—Containing bitumen or constituting the source of bitumen.

Bituminous Emulsion.—A liquid mixture in which minute globules of bitumen are held in suspension in water or a watery solution.

Cut-Back Products.—Petroleum or tar residuums which have been fluxed with distillates.

Flux.—Bitumens, generally liquid, used in combination with harder bitumens for the purpose of softening the latter.

Liquid Bituminous Materials.—Those having a penetration at 25° C. (77° F.), under a load of 50 g. applied for 1 second, of more than 350.

Semi-Solid Bituminous Materials.—Those having a penetration at 25° C. (77° F.), under a load of 100 g. applied for 5 seconds, of more than 10, and a penetration at 25° C. (77° F.), under a load of 50 g. applied for 1 second, of not more than 350.

Solid Bituminous Materials.—Those having a penetration at 25° C. (77° F.), under a load of 100 g. applied for 5 seconds, of not more than 10.

Relating Specifically to Petroleum or Asphalts:

Asphalts.—Solid or semi-solid native bitumens, solid or semi-solid bitumens obtained by refining petroleum, or solid or semi-solid bitumens which are combinations of the bitumens mentioned with petroleums or derivatives thereof, which melt upon the application of heat and which consist of a mixture of hydrocarbons and their derivatives of complex structure, largely cyclic and bridge compounds.

Artificial Asphalt.—Recommended that the use of term be discontinued.

Asphalt Cement.—A fluxed or unfluxed asphalt specially prepared as to quality and consistency for direct use in the manufacture of bituminous pavements, and having a penetration at 25° C. (77° F.) of between 5 and 250, under a load of 100 g. applied for 5 seconds.

Liquid Asphalt.—This is a trade term not subject to definition.

Native Asphalt.—Asphalt occurring as such in nature.

Road Asphalt.—This is a trade term not subject to definition.

Rock Asphalt.—Sandstone or limestone naturally impregnated with asphalt.

Petroleum.—Liquid bitumen occurring as such in nature.

Blown Petroleums.—Semi-solid or solid products produced primarily by the action of air upon liquid native bitumens which are heated during the blowing process.

Topped Petroleum.—Petroleum deprived of its more volatile constituents.

Asphaltenes.—The components of the bitumen in petroleums, petroleum products, malthas, asphalt cements and solid native bitumens, which are soluble in carbon disulphide but insoluble in paraffin naphthas.

Carbenes.—The components of the bitumen in petroleums, petroleum products, malthas, asphalt cements and solid native bitumens, which are soluble in carbon disulphide but insoluble in carbon tetrachloride.

Relating Specifically to Tars and Pitches:

Tars.—Bitumens which yield pitches upon fractional distillation and which are produced as distillates by the destructive distillation of bitumens, pyrobitumens or organic materials.

Coal Tar.—The mixture of hydrocarbon distillates, mostly unsaturated ring compounds, produced in the destructive distillation of coal.

Gas-House Coal Tar.—Coal tar produced in gas-house retorts in the manufacture of illuminating gas from bituminous coal.

Coke-Oven Tar.—Coal tar produced in by-product coke ovens in the manufacture of coke from bituminous coal.

Oil-Gas Tars.—Tars produced by cracking oil vapors at high temperatures in the manufacture of oil gas.

Water-Gas Tars.—Tars produced by cracking oil vapors at high temperatures in the manufacture of carburetted water-gas.

Dehydrated Tars.—Tars from which all water has been removed.

Refined Tar.—Tar freed from water by evaporation or distillation which is continued until the residue is of desired consistency; or a product produced by fluxing tar residuum with tar distillate.

Dead Oils.—Oils with a density greater than water which are distilled from tars.

Pitches.—Solid residues produced in the evaporation or distillation of bitumens, the term being usually applied to residues obtained from tars.

Straight-run Pitch.—A pitch run to the consistency desired, in the initial process of distillation, without subsequent fluxing

Free Carbon in Tars.—Organic matter which is insoluble in carbon disulfide.

Relating Specifically to Tests:

Normal Temperature.—As applied to laboratory observations of the physical characteristics of bituminous materials, is 25° C. (77° F.).

Consistency.—The degree of solidity or fluidity of bituminous materials.

Fixed Carbon.—The organic matter of the residual coke obtained upon burning hydrocarbon products in a covered vessel in the absence of free oxygen.

Penetration.—The consistency of a bituminous material expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time and temperature. Where the conditions of test are not specifically mentioned, the load, time and temperature are understood to be 100 g., 5 seconds, and 25° C. (77° F.), respectively, and the units of penetration to indicate hundredths of a centimeter.

Viscosity.—The measure of the resistance to flow of a bituminous material, usually stated as the time of flow of a given amount of the material through a given orifice.

II. NON-BITUMINOUS MATERIALS.

Relating in General to Non-Bituminous Materials:

Aggregate.—The inert material, such as sand, gravel, shell, slag or broken stone or combinations thereof, with which the cementing material is mixed to form a mortar or concrete.

Matrix.—The binding material or mixture of binding material and fine aggregate in which the large aggregate is embedded or held in place.

Crusher-Run.—The total unscreened product of a stone crusher.

Stone Chips.—Small angular fragments of stone containing no dust.

Tailings.—Stones which after going through the crusher do not pass through the largest openings of the screen.

Rubble.—Rough stones of irregular shapes and sizes, broken from larger masses either naturally or artificially, as by geological action, in quarrying, or in stone cutting or blasting.

Relating Specifically to Materials:

Bank Gravel.—Gravel found in natural deposits, usually more or less intermixed with fine material, such as sand or clay, or combinations thereof; gravelly clay, gravelly sand, clayey gravel and sandy gravel, indicate the varying proportions of the materials in the mixture.

Clinker.—Generally a fused or partly fused by-product of the combustion of coal, but also including lava and Portland-cement clinker, and partly vitrified slag and brick.

Chert.—Compact silicious rock formed of calcedonic or opaline silica, or both.

Granite.—A granitoid igneous rock consisting of quartz, orthoclase, more or less oligoclase, biotite and muscovite.

Granitoid.—A textural term to describe those igneous rocks which are entirely composed of recognizable minerals.

Slag.—Fused or partly fused compounds of silica in combination with lime or other bases, resulting in secondary products from the reduction of metallic ores.

Soil.—A mixture of fine earthy material with more or less organic matter resulting from the growth and decomposition of vegetation or animal matter.

Relating Specifically to Tests:

Mesh.—The square opening of a sieve.

Screen.—In laboratory work an apparatus, in which the apertures are circular, for separating sizes of material.

Sieve.—In laboratory work an apparatus, in which the apertures are square, for separating sizes of material.

STANDARD SPECIFICATIONS
FOR
FOUNDRY COKE.

Serial Designation: D 17–16.

These specifications are issued under the fixed designation D 17; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916.

I. CHEMICAL PROPERTIES AND TESTS.

(*A*) *Sampling.*

Unit of Sampling. 1. Each carload, or its equivalent, shall be considered as a unit.

Method of Sampling. 2. (*a*) The sample shall be taken from the exposed ur-s face of the car, by knocking off with a hammer a piece approximately the size of a walnut, at regular intervals of 18 in. along three lines running from one end of the car to the other. One of these lines shall pass through the center of the car and the other two lines shall be 2 ft. from the respective sides of the car.

(*b*) The intervals of sampling along the three lines may be measured by using a hammer with a handle 18 in. long, breaking off a piece of coke the size of a walnut at each point where the head of the hammer rests, regardless of the appearance of the particular piece that happens to occur under the head of the hammer.

Quantity of Gross Sample. 3. The total quantity of sample collected in the above manner shall not be less than 2 pecks.

Reduction of Gross Sample, Without Regard to Moisture. 4. When the total moisture content is not to be determined, the entire gross sample shall be crushed to pass through a screen having 4 meshes to the linear inch, under such conditions as shall prevent loss or the accidental admixture of foreign matter. The crushing shall be done mechanically with a jaw crusher, or by hand on a chilled iron or hard steel plate by impact of a chilled iron or hard steel tamping bar, hammer or sledge, avoiding all rubbing action, otherwise the ash content of the sample will be materially increased by the addition of iron from the crushing apparatus, even though hardened steel or chilled iron is used.

After all the gross sample has been passed through the 4-mesh screen, it shall be mixed on a strong, closely woven cloth about 5 ft. square by raising successively the four sides of the cloth, thus rolling the sample about until thoroughly mixed. The four corners of the cloth shall then be gathered up, and the sample shall be formed in a conical pile and reduced in quantity by quartering as follows:

The cone shall be flattened, its apex being pressed down so that each quarter contains the material originally in it. The flattened mass shall then be divided into four equal quarters. The diagonally opposite quarters shall then be removed and discarded and the space that they occupied brushed clean. The two remaining quarters shall be successively mixed, coned and quartered on the cloth as before, until two opposite quarters shall weigh not less than 5 lb., which shall then be placed in a suitable container for transportation to the laboratory. In case duplicate laboratory samples are desired, the rejected portions of the original 4-mesh sample shall be combined, mixed and quartered down to a similar 5-lb. sample.

Optional Use of Standard Sample for Moisture Determination

5. The sample prepared by the above method may, at the option of the purchaser, be used for an approximate moisture determination. In such cases the gross sample shall be immediately crushed and reduced to the 5-lb. laboratory sample as rapidly as possible, to minimize the loss of moisture. The container for shipment to the laboratory shall be moisture-tight. Since the sample obtained by this method will usually show less than the true moisture content of the gross sample, the purchaser shall have the privilege of a special moisture sample as hereinafter provided, if the standard sample shows more than 3 per cent moisture.

Special Moisture Sample.

6. The special moisture sample shall consist of not less than 2 pecks of walnut size. It shall be taken in the manner described in Section 2, and shall be placed, immediately after collection, in a moisture-tight container for transportation to the laboratory. The car shall be weighed at the time the special moisture sample is collected.

Resampling

7. In case of disagreement between buyer and seller, an independent chemist, mutually agreed upon, shall be employed to sample and analyze the coke, the cost to be borne by the party at fault.

The resample shall be taken and prepared as prescribed in the foregoing sections, except that the minimum quantity of gross sample shall be not less than 1 bushel in volume, taken at intervals of 18 in. on six equidistant lines parallel to the side of the car.

(*B*) *Chemical Analysis.*

Method of Analysis. 8. The sample received at the laboratory shall be prepared for analysis, and the percentage of moisture, volatile matter, fixed carbon, ash, and sulfur shall be determined as specified in the Standard Methods for Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.

Chemical Composition. 9. The dry coke shall not exceed the following limits in chemical composition:

Volatile matter	not over	2.0	per cent
Fixed carbon	not under	86.0	"
Ash	not over	12.0	"
Sulfur	" "	1.0	"

II. REJECTION.

Deduction for Excess Moisture. 10. (*a*) In case the original standard sample was taken in accordance with Section 5 and showed more than 3 per cent moisture, the purchaser shall have the option of taking a special moisture sample according to Section 6, and of deducting the moisture found in excess of 3 per cent, from the weight of coke found on reweighing the car at the time the special moisture sample was taken.

(*b*) In case the original standard sample was taken with special regard to moisture in accordance with Section 6, the purchaser shall have the option of deducting the moisture in excess of 3 per cent from the weight of coke, provided that the car was weighed at the time of sampling.

Rejection. 11. Coke which fails to conform to the limits of chemical composition given in Section 9 will be rejected, and the seller shall be notified within 5 working days from the date of sampling.

STANDARD METHOD
OF
SAMPLING COAL.

Serial Designation: D 21 – 16.

This method is issued under the fixed designation D 21; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916.

This method was approved March 28, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

It is imperative that every sample be collected and prepared carefully and conscientiously and in strict accordance with the standard methods described herein, for if the sampling is improperly done, the sample will be in error, and it may be impossible or impracticable to take another sample; but if an analysis is in error, another analysis can easily be made of the original sample.

Gross samples of the quantities designated herein must be taken whether the coal to be sampled consists of a few tons or several hundred tons, because of the following cardinal principle in sampling coal that must be recognized and understood; that is, the effect of the chance inclusion or exclusion of too many or too few pieces of slate or other impurities in what, or from what, would otherwise have been a representative sample will cause the analysis to be in error accordingly, regardless of the tonnage sampled. For example, the chance inclusion or exclusion of 10 lb. too much or too little of impurities in or from an otherwise representative sample of 100 lb. would cause the analysis to show an error in ash content and in heat units of approximately 10 per cent, whereas for a 1000-lb. sample, the effect would be approximately only 1 per cent, being the same whether the sample is collected from a 1-ton lot or from a lot consisting of several hundred tons.

When this method of sampling is to be employed as a part of any contract or agreement, the following provisions shall be specifically agreed to by the parties to such contract or agreement:

(*a*) The place at which the coal is to be sampled (see Section 1);

(*b*) The approximate size of the sample required when the standard conditions do not apply (see Section 3);

(*c*) The number of samples to be taken or the amount of coal to be represented by each sample when the standard conditions do not apply (see Section 4).

I. FOR ALL DETERMINATIONS EXCEPT TOTAL MOISTURE.

Time of Sampling.

1. The coal shall be sampled when it is being loaded into or unloaded from railroad cars, ships, barges, or wagons, or when discharged from supply bins, or from industrial railway cars, or grab buckets, or from any coal-conveying equipment, as the case may be. If the coal is crushed as received, samples usually can be taken advantageously after the coal has passed through the crusher. Samples collected from the surface of coal in piles or bins, or in cars, ships or barges are generally unreliable.

Size of Increments.

2. To collect samples, a shovel or specially designed tool, or mechanical means shall be used for taking equal portions or increments. For slack or small sizes of anthracite, increments as small as 5 to 10 lb. may be taken, but for run-of-mine or lump coal, increments should be at least 10 to 30 lb.

Collection of Gross Sample

3. The increments shall be regularly and systematically collected, so that the entire quantity of coal sampled will be represented proportionately in the gross sample, and with such frequency that a gross sample of the required amount shall be collected. The standard gross sample shall not be less than 1000 lb., except that for slack coal and small sizes of anthracite in which the impurities do not exist in abnormal quantities or in pieces larger than $\frac{3}{4}$ in., a gross sample of approximately 500 lb. shall be considered sufficient. If the coal contains an unusual amount of impurities, such as slate, and if the pieces of such impurities are very large, a gross sample of 1500 lb. or more shall be collected. The gross sample should contain the same proportion of lump coal, fine coal, and impurities as is contained in the coal sampled. When coal is extremely lumpy, it is best to break a proportional amount of the lumps before taking the various increments of a sample. Provision should be made for the preservation of the integrity of the sample.

Quantity Represented.

4. A gross sample shall be taken for each 500 tons or less, or in case of larger tonnages, for such quantities as may be agreed upon.

Crushing.

5. After the gross sample has been collected, it shall be systematically crushed, mixed, and reduced in quantity to convenient size for transmittal to the laboratory. The sample may be crushed by hand or by any mechanical means, but under such conditions as shall prevent loss or the accidental admixture of foreign matter. Samples of the quantities indicated in Table I shall be crushed so that no pieces of coal and impurities will be greater in any dimension, as judged by eye, than specified for the sample before division into two approximately equal parts.

The method of reducing by hand the quantity of coal in a gross sample shall be carried out as prescribed in Section 6, even should the initial size of coal and impurities be less than indicated in Table I.

TABLE I.

Weight of Sample to be Divided, lb.	Largest Size of Coal and Impurities Allowable in Sample before Division, in.
1000 or over	1
500	$\frac{3}{4}$
250	$\frac{1}{2}$
125	$\frac{3}{8}$
60	$\frac{1}{4}$
30	$\frac{3}{16}$ or 4-mesh screen

Hand Preparation.

6. The progressive reduction in the weight of the sample to the quantities indicated in Table I shall be done by the following methods, which are illustrated in Plate V:

Mixing and Reduction by Discarding Alternate Shovelsful.

(*a*) The alternate-shovel method of reducing the gross sample shall be repeated until the sample is reduced to approximately 250 lb., and care shall be observed before each reduction in quantity that the sample has been crushed to the fineness prescribed in Table I.

The crushed coal shall be shoveled into a conical pile (Figs. 2 or 7, Plate V) by depositing each shovelful of coal on top of the preceding one, and then formed into a long pile in the following manner: The sampler shall take a shovelful of coal from the conical pile and spread it out in a straight line (Figs. 3*A* or 8*A*) having a width equal to the width of the shovel and a length of 5 to 10 ft. His next shovelful shall be spread directly over the top of the first shovelful, but in the opposite direction, and so on back and forth, the pile being occasionally flattened, until all the coal has been formed into one long pile (Figs. 3*B* or 8*B*). The sampler shall then discard half of this pile, proceeding as follows:

Beginning on one side of the pile, at either end, and shoveling from the bottom of the pile, the sampler shall take one shovelful (shovelful No. 1, Figs. 4 or 9) and set it aside; advancing along the side of the pile a distance equal to the width of the shovel, he shall take a second shovelful (shovelful No. 2) and discard it; again advancing in the same direction one shovel width, he shall take a third shovelful (shovelful No. 3) and add it to the first. The fourth (shovelful No. 4) shall be taken in a like manner and discarded, the fifth (shovelful No. 5) retained, and so on, the sampler advancing always in the same direction around the pile so that its size will be gradually reduced in a uniform manner. When the pile is removed, about half of the original quantity of coal should be contained in the new pile formed by the alternate shovelsful which have been retained. (Figs. 5*A* or 10*A* show the retained halves, and Figs. 5*B* or 10*B* the rejected halves.)

Mixing and Reduction by Quartering.

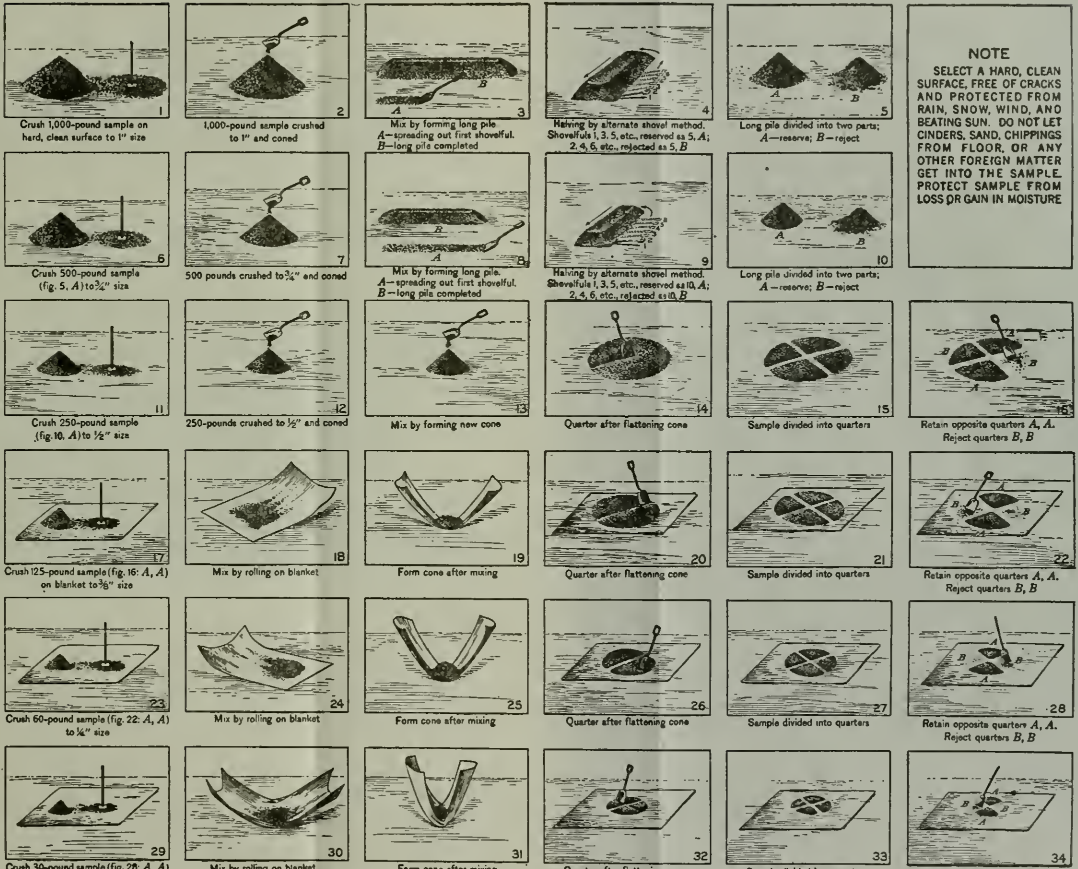
(*b*) After the gross sample has been reduced by the above method to approximately 250 lb., further reduction in quantity shall be by the quartering method. Before each quartering, the sample shall be crushed to the fineness prescribed in Table I.

Quantities of 125 to 250 lb. shall be thoroughly mixed by coning and re-coning (Figs. 12 and 13); quantities less than 125 lb. shall be placed on a suitable cloth, measuring about 6 by 8 ft., mixed by raising first one end of the cloth and then the other (Figs. 18, 24 or 30), so as to roll the coal back and forth, and after being thoroughly mixed shall be formed into a conical pile by gathering together the four corners of the cloth (Figs. 19, 25 or 31). The quartering of the conical pile shall be done as follows:

The cone shall be flattened, its apex being pressed vertically down with a shovel, or board, so that after the pile has been quartered, each quarter will contain the material originally in it. The flattened mass, which shall be of uniform thickness and diameter, shall then be marked into quarters (Figs. 14, 20, 26 or 32) by two lines that intersect at right angles directly under a point corresponding to the apex of the original cone. The diagonally opposite quarters (*BB* in Figs. 16, 22, 28 or 34)

Standard Method of Sampling Coal.

METHOD OF PREPARING A SAMPLE OF COAL BY HAND



FIRST STAGE IN THE PREPARATION OF A 1,000-POUND SAMPLE

1. Crush 1,000-pound sample on hard, clean surface to 1" size
2. 1,000-pound sample crushed to 1" and coned
3. Mix by forming long pile *A*—spreading out first shovelful. *B*—long pile completed
4. Halving by alternate shovel method. Shovelfuls 1, 3, 5, etc., reserved as 5, *A*; 2, 4, 6, etc., rejected as 5, *B*
5. Long pile divided into two parts; *A*—reserve; *B*—reject

SECOND STAGE

6. Crush 500-pound sample (fig. 5, *A*) to ¾" size
7. 500 pounds crushed to ¾" and coned
8. Mix by forming long pile. *A*—spreading out first shovelful. *B*—long pile completed
9. Halving by alternate shovel method. Shovelfuls 1, 3, 5, etc., reserved as 10, *A*; 2, 4, 6, etc., rejected as 10, *B*
10. Long pile divided into two parts; *A*—reserve; *B*—reject

THIRD STAGE

11. Crush 250-pound sample (fig. 10, *A*) to ½" size
12. 250-pounds crushed to ½" and coned
13. Mix by forming new cone
14. Quarter after flattening cone
15. Sample divided into quarters
16. Retain opposite quarters *A*, *A*. Reject quarters *B*, *B*

FOURTH STAGE

17. Crush 125-pound sample (fig. 16: *A*, *A*) on blanket to ⅜" size
18. Mix by rolling on blanket
19. Form cone after mixing
20. Quarter after flattening cone
21. Sample divided into quarters
22. Retain opposite quarters *A*, *A*. Reject quarters *B*, *B*

FIFTH STAGE

23. Crush 60-pound sample (fig. 22: *A*, *A*) to ¼" size
24. Mix by rolling on blanket
25. Form cone after mixing
26. Quarter after flattening cone
27. Sample divided into quarters
28. Retain opposite quarters *A*, *A*. Reject quarters *B*, *B*

SIXTH STAGE

29. Crush 30-pound sample (fig. 28: *A*, *A*) to $\frac{3}{16}$" or 4-mesh size
30. Mix by rolling on blanket
31. Form cone after mixing
32. Quarter after flattening cone
33. Sample divided into quarters
34. The laboratory sample to be taken from *A*, *A*

NOTE

SELECT A HARD, CLEAN SURFACE, FREE OF CRACKS AND PROTECTED FROM RAIN, SNOW, WIND, AND BEATING SUN. DO NOT LET CINDERS, SAND, CHIPPINGS FROM FLOOR, OR ANY OTHER FOREIGN MATTER GET INTO THE SAMPLE. PROTECT SAMPLE FROM LOSS OR GAIN IN MOISTURE

NECESSARY TOOLS: SHOVEL, TAMPER, BLANKET (MEASURING ABOUT 6 BY 8 FT.), BROOM, AND RAKE. USE RAKE FOR RAKING OVER COAL WHEN CRUSHING IT, SO THAT ALL LUMPS WILL BE CRUSHED. SWEEP FLOOR OR BLANKET CLEAN OF ALL DISCARDED COAL AFTER EACH TIME SAMPLE IS HALVED OR QUARTERED.

shall then be shoveled away and discarded and the space that they occupied brushed clean. The coal remaining shall be successively crushed, mixed, coned, and quartered until the sample is reduced to the desired quantity.

(*c*) The 30-lb. quantity (Fig. 29) shall be crushed to $\frac{3}{16}$-in. or 4-mesh size, mixed, coned, flattened and quartered. The laboratory samples shall include all of one of the quarters, or all of two opposite quarters (Fig. 34), as may be required. The laboratory sample shall be immediately placed in a suitable container and sealed in such a manner as to preclude tampering.

Mechanical Preparation

7. Only such mechanical means as will give equally representative samples shall be used in substitution for the hand method of preparation herein standardized.

II. FOR THE DETERMINATION OF TOTAL MOISTURE.

Collection of Moisture Sample.

8. The special moisture sample shall weigh approximately 100 lb., and shall be accumulated by placing in a waterproof receptacle with a tight-fitting and waterproof lid small equal parts of freshly taken increments of the standard gross sample. The accumulated moisture sample shall be rapidly crushed and reduced mechanically or by hand to about a 5-lb. quantity, which shall be immediately placed in a container and sealed airtight and forwarded to the laboratory without delay.

Use of Standard Sample.

9. Only when equally representative results will be obtained shall the standard gross sample be used instead of the special moisture sample for the determination of total moisture.

STANDARD METHODS
OF
LABORATORY SAMPLING AND ANALYSIS OF COAL.

Serial Designation: D 22–21.

These methods are issued under the fixed designation D 22; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1916; Revised, 1921.

PREPARATION OF LABORATORY SAMPLES.

Apparatus.

Air-Drying Oven.—The oven is to be used for air-drying wet samples and may be of the form shown in Fig. 1. This is not absolutely necessary but is economical where many wet samples are received.[1]

Galvanized-Iron Pans 18 by 18 by 1.5 in. Deep.—For air-drying wet samples.

Balance or Solution Scale.—For weighing the galvanized-iron pans with samples. It should have a capacity of 5 kg. and be sensitive to 0.5 g.

Jaw Crusher.—For crushing coarse samples to pass a 4-mesh sieve.

Roll Crusher or Coffee-Mill Type of Grinder.—For reducing the 4-mesh product to 20-mesh. The coffee-mill type of grinder should be entirely enclosed and have an enclosed hopper and a receptacle capable of holding 10 lb. of coal. This is to reduce the moisture losses while crushing.

Abbé Ball Mill, Planetary Disk Crusher, Chrome-Steel Bucking Board, or any Satisfactory Form of Pulverizer.—For reducing the 20-mesh product to 60-mesh. The porcelain jars for the ball mill should be approximately 9 in. in diameter and 10 in. high. The flint pebbles should be smooth, hard and well rounded.

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[1] For details of air-drying oven see Bownocker, Lord and Somermeier, "Coal," *Bulletin No. 9*, 4th Series, Ohio Geological Survey, p. 312 (1908); or F. M. Stanton and A. C. Fieldner, "Methods of Analyzing Coal and Coke," *Technical Paper No. 8*, Bureau of Mines, p. 4 (1912) or E. E. Somermeier, "Coal, Its Composition, Analysis, Utilization and Valuation," p. 71, McGraw-Hill Book Co. (1912).

A Large Riffle Sampler, with $\frac{1}{2}$ or $\frac{5}{8}$-in. Divisions.—For reducing the 4-mesh sample to 10 lb. (Fig. 2).[1]

A Small Riffle Sampler, with $\frac{1}{4}$ or $\frac{3}{8}$-in. Divisions.—For dividing down the 20 and 60-mesh material to a laboratory sample (Fig. 2).

An 8-in. No. 60 Bureau of Standards Standard Screen Scale Sieve with Cover and Receiver.

Containers for Shipment to Laboratory.—Samples in which the moisture content is important should always be shipped in moisture-tight containers. A galvanized-iron or tin can with a screw top which is sealed with a rubber gasket and adhesive tape is best adapted to this purpose. Glass fruit jars sealed with rubber gaskets may be used, but require very careful packing to avoid breakage in transit. Samples in which the moisture content is of no importance need no special protection from loss of moisture.

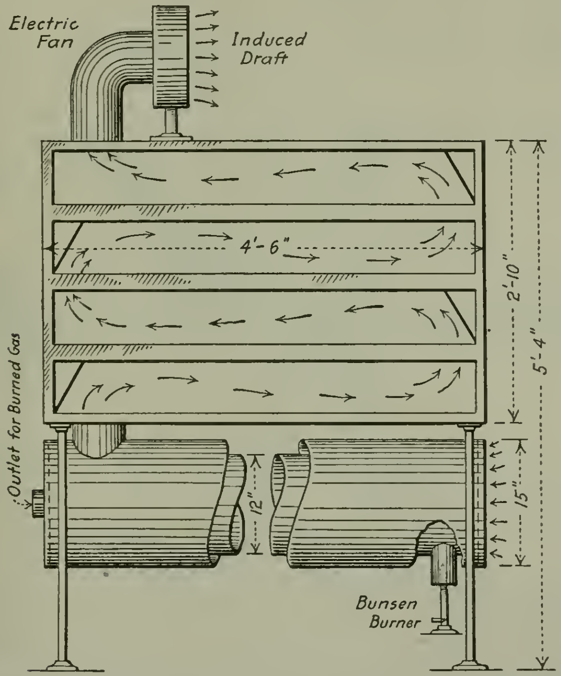

FIG. 1.—Drier for Coarse Samples. The Outlet for Air at the Top may be connected with a Chimney or any other Device which will furnish a Suitable Draft. (*Bulletin No. 9*, Geological Survey of Ohio, p. 312.)

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[1] E. E. Somermeier, "Coal, Its Composition, etc.," McGraw-Hill Book Co. (1912).

METHOD OF SAMPLING.

(*A*) *When Coal Appears Dry.*

If the sample is coarser than 4-mesh (0.20 in.) and larger in amount than 10 lb., quickly crush it with the jaw crusher to pass a 4-mesh sieve and reduce it on the larger riffle sampler to 10 lb.;[1] then crush at once to 20-mesh by passing through rolls or an enclosed grinder, and take, without sieving, a 60-g. total moisture sample, immediately after the material has passed through the crushing apparatus. This sample should be taken with a spoon from various parts of the 20-mesh product, and should be placed directly in a rubber-stoppered bottle.

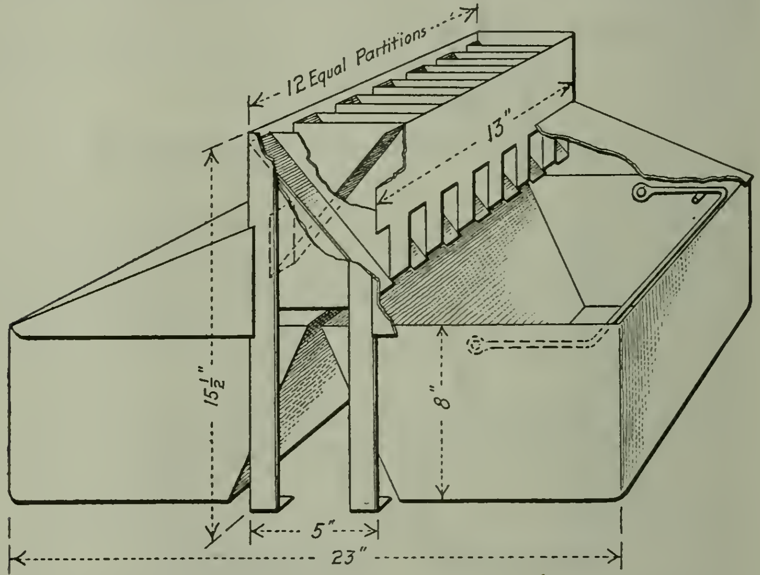

FIG. 2.—Riffle Sampler. (*Bulletin No. 9*, Geological Survey of Ohio, p. 213.)

Thoroughly mix the main portion of the sample, reduce on the small riffle sampler to about 120 g., and pulverize to 60-mesh by any suitable apparatus without regard to loss of moisture. After all the material has been passed through the 60-mesh sieve, mix and divide it on the small riffle sampler to 60 g. Transfer the final sample to a 4-oz. rubber-stoppered bottle. Determine moisture in both the 60 and the 20-mesh samples by the method given under moisture.

Computation.—Compute the analysis of the 60-mesh coal, which has become partly air-dried during sampling, to the dry-coal basis, by dividing each result by 1 minus its content of moisture. Compute the analysis of the coal "as received" from the dry-coal analysis by multiplying by 1 minus the total moisture found in the 20-mesh sample.

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[1] If the sample is crushed to pass a 6-mesh screen it may be reduced to 5 lb.

(B) *When Coal Appears Wet.*

Spread the sample on tared pans, weigh, and air-dry at room temperature, or in the special drying oven, shown in Fig. 1, at 10 to 15° C. above room temperature, and weigh again. The drying should be continued until the loss in weight is not more than 0.1 per cent per hour. Complete the sampling as under dry coal.

Computation.—Correct the moisture found in the 20-mesh, air-dried sample to total moisture "as received," as follows:

$$\frac{100-\text{percentage of air-drying loss}}{100}\times(\text{percentage of moisture in 20-mesh coal})$$
$$+\ (\text{percentage of air-drying loss})=(\text{total moisture ``as received.''})$$

Compute the analysis to "dry-coal" and "as-received" bases as under dry coal, using for the "as-received" computation the total moisture as found by the formula in place of the moisture found in the 20-mesh coal.

Notes.

Freshly mined or wet coal loses moisture rapidly on exposure to the air of the laboratory, hence the sampling operations between opening the container and taking the 20-mesh total-moisture sample must be conducted with the utmost dispatch and with minimum exposure to air.

The accuracy of the method of preparing laboratory samples should be checked frequently by resampling the rejected portions and preparing a duplicate sample. The ash in the two samples should not differ more than the following limits:

No carbonates present	0.4	per cent
Considerable carbonate and pyrite present	0.7	"
Coals with more than 12 per cent ash, containing considerable carbonate and pyrite	1.0	"

DETERMINATION OF MOISTURE.

Apparatus.

Moisture Oven.—This must be so constructed as to have a uniform temperature in all parts and a minimum of air space. It may be of the form shown in Fig. 3. Provision must be made for renewing the air in the oven at the rate of two to four times a minute, with the air dried by passing it through concentrated H_2SO_4.

Capsules with Covers.—A convenient form, which allows the ash determination to be made on the same sample, is No. 2 porcelain capsule, $\frac{7}{8}$ in. deep and $1\frac{3}{4}$ in. in diameter; or a fused silica capsule of similar shape This is to be used with a well-fitting flat aluminum cover, illustrated in Fig. 4.

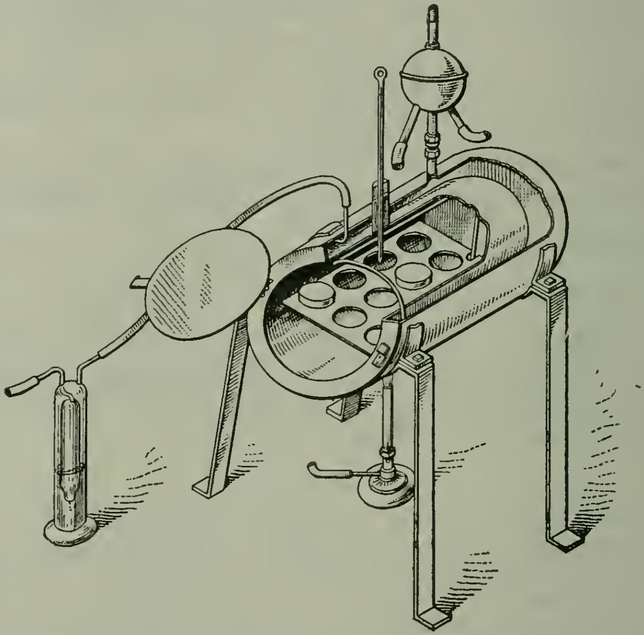

FIG. 3.—Toluene or Glycerin and Water Oven for Determining Moisture. (*Technical Paper No. 76*, Bureau of Mines, p. 16.)

Glass capsules with ground-glass caps may also be used. They should be as shallow as possible, consistent with convenient handling.

METHOD.

(*A*) *Sixty-Mesh Sample.*

Heat the empty capsules under the conditions at which the coal is to be dried, stopper or cover, cool over concentrated H_2SO_4, sp. gr. 1.84, for 30 minutes, and weigh. Dip out with a spoon or spatula from the sample bottle approximately 1 g. of coal; put this quickly into the capsule, close, and weigh at once.

An alternative procedure (more open to error), after transferring an amount slightly in excess of 1 g., is to bring to exactly 1 g. in weight (±0.5 mg.) by quickly removing the excess weight of coal with a spatula. The utmost dispatch must be used in order to minimize the exposure of the coal until the weight is found.

After removing the covers, quickly place the capsules in a pre-heated oven (at 104 to 110° C.) through which passes a current of air dried by concentrated H_2SO_4. Close the oven at once and heat for 1 hour. Then open the oven, cover the capsules quickly and place them in a desiccator over concentrated H_2SO_4. When cool, weigh.

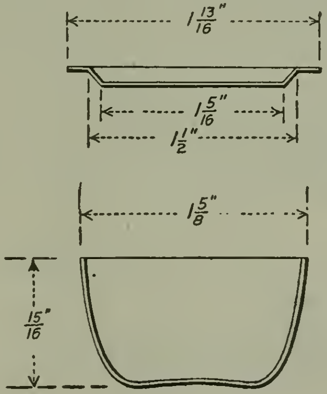

FIG. 4.—Porcelain Capsule with Flat Aluminum Cover.

(B) Twenty-mesh sample.

Use 5-g. samples, weighed with an accuracy of 2 mg., and heat for 1½ hours; the procedure is otherwise the same as with the 60-mesh sample. Methods of greater accuracy for the determination of moisture are given in the preliminary report.

The permissible differences in duplicate determinations are as follows:

	SAME ANALYST, PER CENT.	DIFFERENT ANALYSTS, PER CENT.
Moisture under 5 per cent	0.2	0.3
" over 5 "	0.3	0.5

DETERMINATION OF ASH.

APPARATUS.

Gas or Electric Muffle Furnace.—The muffle should have good air circulation and be capable of having its temperature regulated between 700 and 750° C.

Porcelain Capsules.—No. 2 porcelain capsules, ⅞ in. deep and 1¾ in. in diameter, or similar shallow dishes.

METHOD.

Place the porcelain capsules containing the dried coal from the moisture determination in a cold muffle furnace, or on the hearth at a low temperature, and gradually heat to redness at such a rate as to avoid mechanical loss from too rapid expulsion of volatile matter. Finish the ignition to constant weight (±0.001 g.) at a temperature between 700 and 750° C. Cool in a desiccator, and weigh as soon as cold.

The permissible differences in duplicate determinations are as follows:

	SAME ANALYST, PER CENT.	DIFFERENT ANALYSTS, PER CENT.
No carbonates present	0.2	0.3
Carbonates present	0.3	0.5
Coals with more than 12 per cent of ash, containing carbonates and pyrite	0.5	1.0

NOTES.

Before replacing the capsules in the muffle for ignition to constant weight, the ash should be stirred with a platinum or nichrome wire. Stirring once or twice before the first weighing hastens complete ignition.

The result obtained by this method is "uncorrected" ash. For "corrected" ash see the preliminary report. The actual mineral matters in the original coal are usually very different in weight and composition from the weight of the "uncorrected" ash.

DETERMINATION OF VOLATILE MATTER.

APPARATUS.

Platinum Crucible with Tightly Fitting Cover.—The crucible should be of not less than 10 nor more than 20-cc. capacity; of not less than 25 nor more than 35 mm. in diameter; of not less than 30 nor more than 35 mm. in height.

Vertical Electric Tube Furnace; or a Gas or Electrically Heated Muffle Furnace.—The furnace may be of the form as shown in Fig. 5. It is to be regulated to maintain a temperature of 950° C. (±20° C.) in the crucible, as shown by a thermocouple kept in the furnace. A suitable form of electric furnace is shown in Fig. 5. If the determination of volatile matter is not an essential feature of the specifications under which the coal is bought, a Meker burner may be used.

METHOD.

Weigh 1 g. of the coal in a weighed 10 to 20-cc. platinum crucible, close with a capsule cover, and place on platinum or nichrome-wire supports in the furnace chamber, which must be at a temperature of 950° C. (±20° C.). After the more rapid discharge of volatile matter has subsided, as shown by the disappearance of the luminous flame, tap the cover lightly to more perfectly seal the crucible and thus guard against the admission of air. After heating exactly 7 minutes, remove the crucible from the furnace and, without disturbing the cover, allow it to cool. Weigh as soon as cold. The loss of weight minus moisture equals the volatile matter.

Modification for Sub-Bituminous Coal, Lignite, and Peat.—Mechanical losses are incurred on suddenly heating peat, sub-bituminous coal, and lignite; therefore they must be subjected to a preliminary gradual heating for 5 minutes; this is best done by playing the flame of a burner upon the bottom of the crucible in such a manner as to bring about the discharge of volatile matter at a rate not sufficient to cause sparking. After the preliminary heating, transfer the crucible to the volatile-matter furnace and heat for 6 minutes at 950° C. as in the regular method.

The permissible differences in duplicate determinations are as follows:

	SAME ANALYST, PER CENT.	DIFFERENT ANALYSTS, PER CENT.
Bituminous coals	0.5	1.0
Lignites	1.0	2.0

NOTES.

The cover should fit closely enough so that the carbon deposit from bituminous and lignite coals does not burn away from the under side.

Regulation of temperature to within the prescribed limits is important.

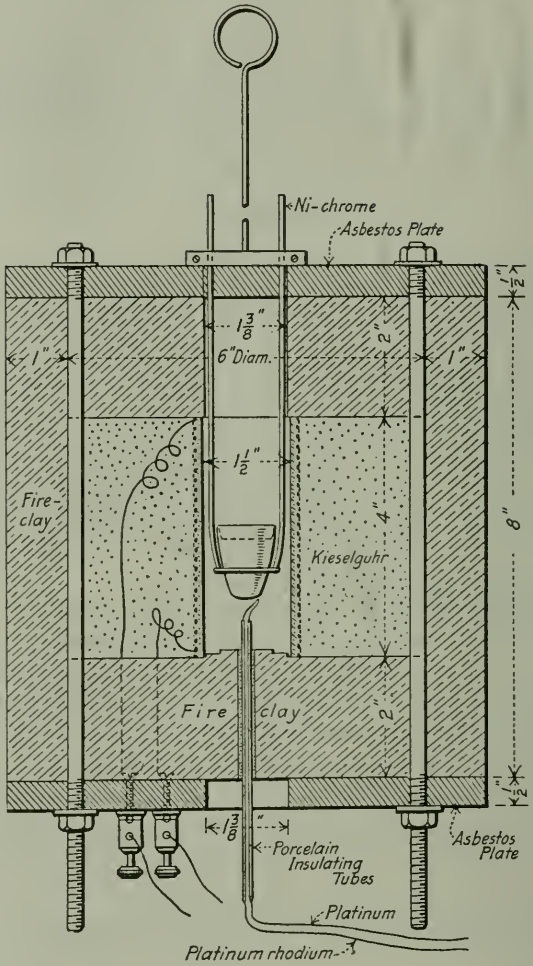

FIG. 5.—Electric Tube Furnace for Determining Volatile Matter. For 110-volt Alternating Current, 60 ft. of Nichrome Wire, No. 17 B. & S. gage will give the required temperature. The temperature must be controlled by an external resistance. (*Technical Paper No. 76*, Bureau of Mines, p. 21.)

DETERMINATION OF FIXED CARBON.

Compute fixed carbon as follows:

100 – (moisture + ash + volatile matter) = percentage of fixed carbon.

DETERMINATION OF SULFUR BY THE ESCHKA METHOD.

APPARATUS.

Gas or Electric Muffle Furnace, or Burners.—For igniting coal with the Eschka mixture and for igniting the $BaSO_4$.

Porcelain, Silica, or Platinum Crucibles or Capsules.—For igniting coal with the Eschka mixture.

No. 1 porcelain capsule, 1 in. deep and 2 in. in diameter. This capsule, because of its shallow form, presents more surface for oxidation and is more convenient to handle than the ordinary form of crucible.

No. 1 porcelain crucibles, shallow form, and platinum crucibles of similar size may be used. Somewhat more time is required to burn out the coal, owing to the deeper form, than with the shallow capsules described above.

No. 0 or 00 porcelain crucibles, or platinum, alundum or silica crucibles of similar size are to be used for igniting the $BaSO_4$.

SOLUTIONS AND REAGENTS.

Barium Chloride.—Dissolve 100 g. of $BaCl_2 \cdot 2H_2O$ in 1000 cc. of distilled water.

Saturated Bromine Water.—Add an excess of bromine to 1000 cc. of distilled water.

Eschka Mixture.—Thoroughly mix 2 parts (by weight) of light calcined MgO and 1 part of anhydrous Na_2CO_3. Both materials should be as free as possible from sulfur.

Methyl Orange.—Dissolve 0.02 g. in 100 cc. of hot distilled water and filter.

Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20, and 500 cc. of distilled water.

Normal Hydrochloric Acid.—Dilute 80 cc. of HCl, sp. gr. 1.20, to 1 liter with distilled water.

Sodium Carbonate.—A saturated solution, approximately 60 g. of crystallized or 22 g. of anhydrous Na_2CO_3 in 100 cc. of distilled water.

Sodium-Hydroxide Solution.—Dissolve 100 g. in 1 liter of distilled water. This solution may be used in place of the Na_2CO_3 solution.

METHOD.

Preparation of Sample and Mixture.—Thoroughly mix on glazed paper 1 g. of coal and 3 g. of Eschka mixture. Transfer to a No. 1 porcelain capsule, 1 in. deep and 2 in. in diameter, or a No. 1 crucible or a platinum crucible of similar size, and cover with about 1 g. of Eschka mixture.

Ignition.—On account of the amount of sulfur contained in artificial gas, the crucible shall be heated over an alcohol, gasoline or natural gas flame as in procedure (*a*) below, or in a gas or electrically heated muffle, as in procedure (*b*) below. The use of artificial gas for heating the coal and Eschka mixture is permissible only when the crucibles are heated in a muffle.

(*a*) Heat the crucible, placed in a slanting position on a triangle, over a very low flame to avoid rapid expulsion of the volatile matter, which tends to prevent complete absorption of the products of combustion of the sulfur. Heat the crucible slowly for 30 minutes, gradually increasing the temperature and stirring after all black particles have disappeared, which is an indication of the completeness of the procedure.

(*b*) Place the crucible in a cold muffle and gradually raise the temperature to 870–925° C. (cherry-red heat) in about 1 hour. Maintain the maximum temperature for about 1½ hours and then allow the crucible to cool in the muffle.

Subsequent Treatment.—Remove and empty the contents into a 200-cc. beaker and digest with 100 cc. of hot water for ½ to ¾ hour, with occasional stirring. Filter and wash the insoluble matter by decantation. After several washings in this manner, transfer the insoluble matter to the filter and wash 5 times, keeping the mixture well agitated. Treat the filtrate, amounting to about 250 cc., with 10 to 20 cc. of saturated bromine water, make slightly acid with HCl and boil to expel the liberated bromine. Make just neutral to methyl orange with NaOH or Na_2CO_3 solution, then add 1 cc. of normal HCl. Boil again and add slowly from a pipette, with constant stirring, 10 cc. of a 10-per-cent solution of $BaCl_2 \cdot 2H_2O$. Continue boiling for 15 minutes and allow to stand for at least 2 hours, or preferably over night, at a temperature just below boiling. Filter through an ashless filter paper and wash with hot distilled water until a $AgNO_3$ solution shows no precipitate with a drop of the filtrate. Place the wet filter containing the precipitate of $BaSO_4$ in a weighed platinum, porcelain, silica or alundum crucible, allowing a free access of air by folding the paper over the precipitate loosely to prevent spattering. Smoke the paper off gradually and at no time allow it to burn with flame. After the paper is practically consumed, raise the temperature to approximately 925° C. and heat to constant weight.

The residue of MgO, etc., after leaching, should be dissolved in HCl and tested with great care for sulfur. When an appreciable amount is found this should be determined quantitatively. The amount of sulfur retained is by no means a negligible quantity.[1]

Blanks and Corrections.—In all cases a correction must be applied either (1) by running a blank exactly as described above, using the same amount of all reagents that were employed in the regular determination, or more surely (2) by determining a known amount of sulfate added to a solution of the reagents after these have been put through the prescribed series of operations. If this latter procedure is adopted and carried out, say, once a week or whenever a new supply of a reagent must be used, and for a series of solutions covering the range of sulfur content likely to be met with in coals, it is only necessary to add to or subtract from the weight of $BaSO_4$ obtained from a coal, whatever deficiency or excess may have been found in the appropriate "check" in order to obtain a result that is more certain to be correct than if a "blank" correction as determined by the former procedure is applied. This is due to the fact that the solubility error for $BaSO_4$, for the amounts of sulfur in question and the conditions of precipitation prescribed, is probably the largest one to be considered. $BaSO_4$ is soluble[2] in acids and even in pure water, and the solubility limit is reached almost immediately on contact with the solvent. Hence, in the event of using reagents of very superior quality or of exercising more than ordinary precautions, there may be no apparent "blank," because the solubility limit of the solution for $BaSO_4$ has not been reached or at any rate not exceeded.

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[1] *Journal*, Am. Chem. Soc., Vol. 21, p. 1125 (1899).

[2] *Journal*, Am. Chem. Soc., Vol. 32, p. 588 (1910); Vol. 33, p. 829 (1911).

As shown in the preliminary report,[1] the Atkinson and sodium-peroxide methods give results in close agreement with the Eschka method. Register[2] has shown that if 5 per cent of nitrogen is present in the gases contained in the bomb calorimeter the sulfur of a coal is almost completely oxidized to H_2SO_4 and the washings of the calorimeter may be used for the determination of sulfur.

The permissible differences in duplicate determinations are as follows:

	SAME ANALYST, PER CENT.	DIFFERENT ANALYSTS PER CENT.
Sulfur under 2 per cent..........	0.05	0.10
" over 2 "	0.10	0.20

DETERMINATION OF PHOSPHORUS IN ASH.

Method No. 1. To Cover All Cases.—To the ash from 5 g. of coal in a platinum capsule is added 10 cc. of HNO_3 and 3 to 5 cc. of HF. The liquid is evaporated and the residue fused with 3 g. of Na_2CO_3. If unburned carbon is present 0.2 g. of $NaNO_3$ is mixed with the carbonate. The melt is leached with water and the solution filtered. The residue is ignited, fused with Na_2CO_3 alone, the melt leached and the solution filtered. The combined filtrates, held in a flask, are just acidified with HNO_3 and concentrated to a volume of 100 cc. To the solution, brought to a temperature of 85° C., is added 50 cc. of molybdate solution and the flask is shaken for 10 minutes. If the precipitate does not form promptly and subside rapidly, add enough NH_4NO_3 to cause it to do so. The precipitate is washed six times, or until free from acid, with a 2-per-cent solution of KNO_3, then returned to the flask and titrated with standard NaOH solution. The alkali solution may well be made equal to 0.00025 g. phosphorus per cubic centimeter, or 0.005 per cent for a 5-g. sample of coal, and is 0.995 of one-fifth normal.[3] Or the phosphorus in the precipitate is determined by reduction and titration of the molybdenum with permanganate.

Note on Method No. 1.—The advantage of the use of HF in the initial attack of the ash lies in the resulting removal of silica. Fusion with alkali carbonate is necessary for the elimination of titanium, which if present and not removed will contaminate the phospho-molybdate and is said to sometimes retard its precipitation.

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[1] *Journal of Industrial and Engineering Chemistry*, Vol. 5, p. 5 (1913).

[2] *Ibid.*, Vol. 6, p. 812 (1914).

[3] Ulmann and Buch, *Chemical Engineer*, Vol. 10, p. 130 (1909).

Method No. 2.—When titanium is so low as to offer no objection, the ash is decomposed as under method No. 1, but evaporation is carried only to a volume of about 5 cc. The solution is diluted with water to 30 cc., boiled and filtered. If the washings are turbid they are passed again through the filter. The residue is ignited in a platinum crucible, fused with a little Na_2CO_3, the melt dissolved in HNO_3 and its solution, if clear, added to the main one. If not clear it is filtered. The subsequent procedure is as under method No. 1. The fusion of the residue may be dispensed with in routine work on a given coal if it is certain that it is free from phosphorus.

ULTIMATE ANALYSIS.

CARBON AND HYDROGEN.

The determination of carbon and of hydrogen is made with a weighed quantity of sample in a 25-burner combustion furnace of the Glaser type. The products of combustion are thoroughly oxidized by being passed over red-hot CuO and $PbCrO_4$, and are fixed by absorbing the water in a weighed Marchand tube filled with granular $CaCl_2$ and by absorbing the CO_2 in a Liebig bulb containing a 30-per-cent solution of KOH.

The apparatus used consists of a purifying train, in duplicate, a combustion tube in the furnace, and an absorption train. The purifying train consists of the following purifying reagents arranged in order of passage of air and oxygen through them: H_2SO_4, KOH solution, soda lime, and granular $CaCl_2$. One of the trains is for air and one for oxygen. In the H_2SO_4 and KOH scrubbing bottles the air and the oxygen are made to bubble through about 5 mm. of the purifying reagent. Both purifying trains are connected to the combustion tube by a Y-tube, the joint being made tight by a rubber stopper.

The combustion tube is made of hard Jena glass. Its external diameter is about 21 mm., and its total length is 1 meter. The first 30 cm. of the tube are empty; following this empty space is an asbestos plug (acid-washed and ignited) or in its place a roll of oxidized copper gauze may be used; the next 40 cm. are filled with "wire" CuO; a second asbestos plug separates the copper oxide from 10 cm. of fused $PbCrO_4$, which is held in place by another asbestos plug 20 cm. from the end of the tube. The end of the tube is drawn out for rubber-tubing connection with the absorption train.

The absorption train consists, first, of a Marchand tube filled with granular $CaCl_2$ to absorb moisture. The $CaCl_2$ should be saturated with CO_2 before using. The Marchand tube is followed by a Liebig bulb containing a 30-per-cent KOH solution, in which any possible impurities, as ferrous iron or nitrites, have been oxidized by a little $KMnO_4$. A guard tube, containing granular $CaCl_2$ and soda lime, is attached to the Liebig bulb to absorb any CO_2 escaping the KOH solution and any water evaporating from that solution.

The train is connected to an aspirator which draws the products of combustion through the entire train. A guard tube of $CaCl_2$ prevents moisture from running back into the absorption train. The suction is maintained constant by a Mariotte flask. The advantage of aspirating the gases through the train rather than forcing them through by pressure is that the pressure on the rubber connections is from the outside, so that gas-tight connections are more easily maintained than if the pressure is on the inside of the tube. The connections are made as tight as possible. The usual test for tightness is to start aspiration at the rate of about three bubbles of air per second through the potash bulb, and then to close the inlet for air and oxygen at the opposite end of the train; if there is no more than one bubble per minute in the potash bulb, the apparatus is considered tight.

Before starting a determination when the train has been idle some hours, or after any changes in chemicals or connections, a blank is run by aspirating about 1 liter of air through the train, which is heated in the same manner as if a determination on coal were being made. If the Liebig bulb and the tube containing calcium chloride show a change in weight of less than 0.5 mg. each, the apparatus is in proper condition for use.

A porcelain or platinum boat is provided with a glass weighing tube of suitable size, which is fitted with an accurately ground glass stopper. The tube and empty boat are weighed. Approximately 0.2 g. of the air-dry coal (60-mesh and finer, or better, 100-mesh if much free impurity is present) are quickly placed in the boat. The boat is at once placed in the weighing tube, which is quickly stoppered to prevent moisture change in the coal while weighing, and transferring to the furnace. The absorption tubes are connected and the boat and sample are transferred from the weighing tube to the combustion tube, which should be cool for the first 30 cm. The CuO should be red hot and the $PbCrO_4$ at a dull-red heat. The transfer of the boat from weighing tube to combustion tube should be made as rapidly as possible. As soon as the boat is in place near the asbestos plug at the beginning of the copper oxide the stopper connecting with the purifying train is inserted and the aspiration started with pure oxygen gas at the rate of three bubbles per second. One burner is turned on about 10 cm. back from the boat, and the aspiration is continued carefully until practically all the moisture is expelled from the sample. The heat is then increased very gradually until all the volatile matter has been driven off. In driving off the volatile matter the heat must be applied gradually in order to prevent a too rapid evolution of gas and tar, which may either escape complete combustion or may be driven back into the purifying train. The heat should be slowly increased by turning on more burners under the open part of the tube until the sample is ignited; then the temperature can be increased rapidly, but care should be taken not to melt the combustion tube. Any moisture collecting in the end of the combustion tube or in the rubber connection joining it to the $CaCl_2$ tube is driven over into the $CaCl_2$ tube by carefully warming with a piece of hot tile. The aspiration with oxygen is continued for 2 minutes after the sample ceases to glow, the heat is then turned off and about 1200 cc. of air are aspirated. The absorption bulbs are then disconnected, wiped with a clean cloth, and allowed to cool to the balance-room temperature before weighing.

$$\text{Percentage of hydrogen} = \frac{11.19 \times (\text{increase in weight of } CaCl_2 \text{ tube})}{\text{Weight of sample}}$$

$$\text{Percentage of carbon} = \frac{27.27 \times (\text{increase in weight of KOH bulb})}{\text{Weight of sample.}}$$

The ash in the boat is weighed and carefully inspected for any unburned carbon, which would destroy the value of the determination.

Method with Electrically Heated Combustion Furnace.—An electrically heated combustion furnace of the Heraeus type is used by the Bureau of Mines.[1]

It consists of three independent heaters, two of which are provided with sheave wheels, and are mounted on a track so that they are movable along the tube; the third heater which surrounds the $PbCrO_4$, is stationary.

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[1] *Technical Paper No. 8*, Bureau of Mines, revised edition 1913, p. 22.

The furnace as provided by the manufacturer does not include the small stationary heater. This can be made in the laboratory by winding an alundum tube 12 cm. in length with No. 20 nichrome II wire and enclosing it in a cylinder packed with magnesia-asbestos. The movable heaters have very thin platinum foil, weighing about 9 g. in all, wound on a porcelain tube of 30 mm. internal diameter. The larger one which heats the CuO, is 350 mm. in length, and the smaller one, which heats the sample in the boat, is 200 mm. in length. The Jena glass or fused silica combustion tube, of about 21 mm. external diameter and 900 mm. in length, is supported by an asbestos-lined nickel trough. The current through each heater is regulated independently by separate rheostats, mounted on the frame of the furnace. The two platinum-wound heaters require an average current of about 4.5 amperes at a pressure of 220 volts, although for heating rapidly a larger amperage is necessary.

The oxygen or air entering the combustion tube is purified by passing through a Tauber's drying apparatus, which contains the following reagents arranged in order of the passage of air or oxygen through them: H_2SO_4, for removing possible traces of ammonia, 30-per-cent KOH solution, granular soda lime, and granular $CaCl_2$. One side of the train is connected directly to a Linde oxygen tank, which is provided with a reducing valve for regulating the oxygen pressure; the other side of the train is used for purifying the air supply.

The absorption train consists of a 5-in. U-tube, filled with granular $CaCl_2$ to absorb moisture. Before using, the $CaCl_2$ should be saturated with CO_2 to avoid possible absorption of CO_2 during a determination by any traces of CaO that may be present. This saturating is done most conveniently by placing a quantity of $CaCl_2$ in a large drying jar, and filling the jar with CO_2. After standing over night, dry air is drawn through the jar to remove the CO_2. The treated $CaCl_2$ is kept in well-stoppered bottles.

The $CaCl_2$ tube is connected to a Vanier potash bulb containing a 30-per-cent KOH solution and granular $CaCl_2$. Six to eight determinations can be made without recharging this bulb. The potash bulb is connected to an aspirator through a guard tube containing granular $CaCl_2$ and soda lime, and a Mariotte flask. The Mariotte flask keeps the pressure constant.

In general, the method of determination is the same as the one used with the gas furnace. By moving the heaters toward the end of the tube where the gases enter, and cutting in the electric current, the air can be warmed enough to thoroughly dry the tube and its contents. The current is then cut off from the small heater, and the large heater is moved over the CuO; about 250 mm. of that part of the combustion tube between the two heaters where the boat containing the sample is to be placed is kept exposed. The full current is then turned on the large heater to bring the CuO to a red heat. When this temperature is reached it is necessary to reduce the current with the rheostat to avoid melting the tube. In the meantime the absorption train is weighed and connected, and the boat containing the sample is placed in the exposed and cooler part of the tube between the two heaters.

The current is then passed through the shorter heater. By manipulating the rheostat and by gradually pushing this heater toward the boat, the rate of evaporation of moisture and evolution of volatile matter can be readily controlled.

After combustion is complete, the electric current is turned off the smaller heater and this heater moved back to allow the tube to cool for the next determination. The final aspiration of air and the weighing of the absorption train is conducted as described under the gas-furnace method.

NOTE.

In place of granulated $CaCl_2$, concentrated H_2SO_4 may be used for collecting the water formed by combustion. In such cases the air and oxygen entering the combustion tube and the gas leaving the potash bulb must also be dried by H_2SO_4.

Other suitable forms of absorption vessels than those indicated in the above procedure may be used.

NITROGEN.

The Kjeldahl-Gunning method is recommended for the determination of nitrogen. This method has the advantage over either the simple Kjeldahl or the Gunning method, in requiring less time for the complete oxidation of the organic matter, and in giving the most uniform results.

The Kjeldahl-Gunning Method.—One gram of the coal sample is boiled with 30 cc. of concentrated H_2SO_4, 7 to 10 g. of K_2SO_4, and 0.6 to 0.8 g. of metallic mercury in a 500-cc. Kjeldahl flask until all particles of coal are oxidized and the solution nearly colorless. The boiling should be continued at least 2 hours after the solution has reached the straw-colored stage. The total time of digestion will be from 3 to 4 hours. The addition of a few crystals of $KMnO_4$, after the solution has cooled enough to avoid violent reaction, tends to insure complete oxidation.

After cooling, the solution is diluted to about 200 cc. with cold water. If the dilution with water has warmed the solution, it should be again cooled and the following reagents added: 25 cc. K_2S solution (40 g. K_2S per liter) to precipitate the mercury; 1 to 2 g. of granular zinc to prevent bumping; and finally enough strong NaOH solution (usually 80 to 100 cc.) to make the solution distinctly alkaline. The danger of loss of NH_3 may be minimized by holding the flask in an inclined position while the NaOH solution is being added. The alkaline solution runs down the side of the flask and forms a layer below the lighter acid solution. After adding the alkaline solution, the flask is at once connected to the condensing apparatus and the solution mixed by gently shaking the flask.

The NH_3 is distilled over into a measured amount (10 cc.) of standard H_2SO_4 solution, to which has been added sufficient cochineal indicator for titration. Care should be taken that the glass connecting tube on the end of the condenser dips under the surface of the standard acid. The solution is slowly distilled until 150 to 200 cc. of distillate has passed over. To avoid mechanically entrained alkali passing over into the condenser, the rate of distillation should not exceed 100 cc. per hour. The distillate is titrated with standard NH_3 solution (20 cc. NH_4OH solution $=$ 10 cc. H_2SO_4 solution $=$ 0.05 g. nitrogen). Standard NaOH or KOH solution with methyl orange or methyl red as indicator may be used instead of NH_3 and cochineal.

A blank determination should be made in exactly the same manner as described above, except that 1 g. of pure sucrose (cane sugar) is substituted in place of the coal sample. The nitrogen found in this blank determination is deducted from the result obtained with the coal sample.

The K_2S and NaOH may be dissolved in a single stock solution. Sufficient K_2S is dissolved in the water before adding the NaOH, to make a solution in which the quantity necessary for a nitrogen determination (80 to 100 cc.) contains 1 g. of K_2S. Twelve grams of K_2S and 500 g. of NaOH in one liter of water, are required for the above proportions.

Coke and anthracite should be ground to an impalpable powder, as they are very difficult to oxidize. Even if this is done the digestion may require 12 to 16 hours.

OXYGEN.

There being no satisfactory direct method of determining oxygen, it is computed by subtracting the sum of the percentages of hydrogen, carbon, nitrogen, sulfur, water and ash from 100. The result so obtained is affected by all the errors incurred in the other determinations and especially by the change in weight of the ash-forming constituents on ignition; iron pyrite changes to ferric oxide, increasing the ash and causing a negative error in the oxygen equivalent to three-eighths of the pyritic sulfur. On the other hand, there is always a loss on ignition, of water of composition from the clayey and shaley constituents, CO_2 from carbonates, etc., which tends to compensate the absorption of oxygen.

Corrected Oxygen.—When a more correct oxygen value is desired, it may be obtained by making the corrections indicated in the following formula:

Corrected oxygen $= 100 - [\ (C - C') + (H - H') + N + H_2O + S' +$ corrected ash],

in which

C = total carbon,
C' = carbon of carbonates,
H = total hydrogen less hydrogen of water,
H' = hydrogen from water of composition in clay, shale, etc.,
N = nitrogen,
H_2O = moisture as found at 105° C.,
S' = sulfur not present as pyrite or sulfate. This is usually small. In many types of coal it may be disregarded.
Corrected ash = mineral constituents originally present in the coal. For most purposes this can be determined with sufficient accuracy by adding to the ash, as found, five-eighths of the weight of pyritic sulfur, the CO_2 of carbonates and the water of composition of clay, shale, etc. See also ash determination.

CALORIMETRIC DETERMINATION.

APPARATUS.

Combustion Bombs.—The Atwater, Davis, Emerson, Mahler, Parr, Peters, Williams, or similar bombs may be used. The bomb shall have an inner surface of platinum, gold, porcelain enamel, or other material which is not attacked by HNO_3 and H_2SO_4, or other products of combustion.

Calorimeter Jacket.—The calorimeter must be provided with a water-jacket having a cover to protect the calorimeter from air currents. The jacket must be kept filled with water within 2 or 3° C. of the temperature of the room (except in calorimeters which are totally submerged, where the jacket temperature is controlled by a thermostat) and should be stirred continuously by some mechanical stirring device.

Stirring of the Calorimeter Water.—The water in the calorimeter must be stirred sufficiently well to give consistent thermometer readings while the temperature is rising rapidly. The speed of stirring should be kept constant. A motor-driven screw or turbine stirrer is recommended and the speed should not be excessive. This may be determined by adjusting the temperature of the calorimeter to equality with that of the jacket and allowing the stirrer to run continuously for ten minutes. If the temperature of the calorimeter rises more than about 0°.01 C. in this length of time, the rate of stirring is excessive. Accurate results cannot be obtained when too much energy is supplied by the stirring device or when the rate of stirring is irregular. The portion of the stirring device immersed in the calorimeter should be separated from that outside by non-conducting material, such as hard rubber, to prevent conduction of heat from the motor or outside air.

Thermometers.—Thermometers used shall have been certified by a government testing bureau and shall be used with the corrections given on the certificate. This shall also apply to electrical resistance or thermo-electric thermometers. Correction shall also be made for the temperature of the emergent stem of all mercurial thermometers, and for the "setting" of Beckmann thermometers. For accurate work, either Beckmann or special calorimetric thermometers graduated to 0.01 or 0°.02 C. are required. Such thermometers should be tapped lightly just before each reading to avoid errors caused by the sticking of the mercury meniscus, particularly when the temperature is falling. A convenient method is to mount a small electric buzzer directly on the top of the thermometer and connect it up with a dry cell and a push button. The button should be pressed for a few seconds immediately before each reading.

Oxygen.—The oxygen used for combustions shall be free from combustible material. The bomb when filled should contain at least 5 per cent of nitrogen to insure complete oxidation of the sulfur.[1] The total amount of oxygen contained in the bomb for a combustion shall not be less than 5 g. per gram of coal. But the combustion must be complete, as shown by the absence of any sooty deposit on opening the bomb after firing.

Firing Wire.—The coal in the bomb may be ignited by means of either iron or platinum wire. If iron wire is used, it should be of about No. 34 B. & S. gage and not more than 10 cm. (preferably 5 cm.) should be used at a time. A correction of 1600 calories per gram weight of iron wire burned is to be subtracted from the observed number of calories.

Standardization.—The water equivalent of a calorimeter can best be determined by the use of the standard combustion samples supplied by the Bureau of Standards. The required water equivalent is equal to the weight of the sample multiplied by its heat of combustion per gram and divided by the corrected rise in temperature.

The calorimeter shall be standardized by the combustion of standard samples supplied by the Bureau of Standards, and used according to the directions given in the certificates which accompany them. A standardization shall consist of a series of not less than five combustions of either the same or different standard materials. The conditions as to the amount of water, oxygen, firing wire, method of correcting for radiation, etc., under which these combustions are made shall be the same as for coal combustions. In the case of any disagreement between contracting parties a check standardization may consist of two or more combustions of standardizing samples.

MANIPULATION.

1. *Preparation of Sample.*—The ground sample is to be thoroughly mixed in the bottle and an amount, approximately 1 g., is to be taken out and weighed in the crucible in which it is to be burned. Coals which are likely to be blown out of the

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[1] Register, *Journal of Industrial and Engineering Chemistry*, Vol. 16, p. 812 (1914).

crucible should be briquetted. After weighing, the sample should preferably be immediately placed in the bomb and this closed. This procedure is necessary to avoid sublimation in the use of naphthalene for standardization.

2. *Preparation of the Bomb.*—The firing wire, if iron, should be measured and coiled in a small spiral and connected between the platinum terminals, using, if necessary, a piece of platinum wire somewhat heavier than the iron wire, to make the connection. The platinum and the iron must both be clean. About 0.5 cc. of water should be placed in the bottom of the bomb to saturate with moisture the oxygen used for combustion. When the crucible is put in place in the bomb, the firing wire should touch the coal or briquette of standard material. For the combustion of standardizing samples iron wire is preferable to platinum.

3. *Filling the Bomb with Oxygen.*—Oxygen from the supply tank is to be admitted slowly to avoid blowing the coal from the crucible, and the pressure allowed to reach 20 atmospheres for the larger bombs or about 30 atmospheres for the smaller bombs, so that the bomb shall contain an amount of oxygen sufficient for complete combustion, namely, at least 5 g. per gram of coal, or other combustible. This method of filling will insure 4 per cent of nitrogen in the larger bombs, irrespective of the nitrogen contained in the oxygen.

4. *Calorimeter Water.*—The calorimeter is to be filled with the required amount of distilled water, depending upon the type of calorimeter. The amount may be determined either by measurement in a standardized flask or by weighing. The amount must be kept the same as that used in standardization of the apparatus.

5. *Temperature Adjustments.*—The initial temperature in the calorimeter should be so adjusted that the final temperature, after the combustion, will not be more than 1° C., preferably about 0°.5 C., above that of the jacket, under which conditions the total correction for heat gained from or lost to the surroundings will be small when the rise of temperature is 2 or 3° C. and the effect of evaporation will also be small.

6. *Firing Current.*—The electric current used for firing the charge should be obtained from storage or dry cells having an electro-motive force of not more than 12 volts, since a higher voltage is liable to cause an arc between the firing terminals, introducing additional heat, which cannot be measured with

certainty. The circuit should be closed by means of a switch which should remain closed for not more than 2 seconds. When possible, it is recommended that an ammeter be used in the firing circuit to indicate when the firing wire has burned out.

7. *Method of Making an Observation.*—The bomb when ready for firing, is to be placed in the calorimeter, the firing wires connected, the cover put in place and the stirrer and thermometer so placed as not to be in contact with the bomb or container. The stirrer is then started and after the thermometer reading has become steady, not less than 2 minutes after the stirrer is started, temperatures are read at 1-minute intervals for 5 minutes and the charge is then fired, the exact time of firing being noted. Observations of temperature are then made at intervals depending upon the method to be used for computing the cooling correction. When the temperature has reached its maximum and is falling uniformly, a series of thermometer readings is taken at 1-minute intervals for 5 minutes to determine the final cooling rate.

8. *Titration.*—After a combustion the bomb is to be opened, after allowing the gas to escape, and the inside examined for traces of unburned material or sooty deposit. If these are found, the observations shall be discarded. If the combustion appears complete, the bomb is to be rinsed out thoroughly and the washings titrated with a standard alkali solution (1 cc. = 0.02173 g. HNO_3 = 5 calories) using methyl-orange or methyl-red indicator, to determine the amount of acid formed. A correction of 230 calories per gram of HNO_3 should be subtracted from the total heat observed. An additional correction of 1300 calories per gram of sulfur in the coal should be made for the excess of difference in heats of formation of SO_2 and aqueous H_2SO_4 over the heat of formation of aqueous HNO_3.

COMPUTATION OF RESULTS.

The following method of computation is recommended to take the place of the Pfaundler or other similar formulas for computing the cooling correction (radiation correction).

Observe (1) the rate of rise (r_1) of the calorimeter temperature in degrees per minute for 5 minutes before firing; (2) the time (a) at which the last temperature reading is made immediately before firing; (3) the time (b) when the rise of temperature has reached six-tenths of its total amount (this point can generally be determined by adding to the temperature observed before firing, 60 per cent of the expected[1] temperature rise, and noting the time when this point is reached); (4) the time (c) of a thermometer reading taken when the temperature change has become uniform some 5 minutes after firing; (5) the final rate of cooling (r_2) in degrees per minute for 5 minutes.

The rate r_1 is to be multiplied by the time $b-a$ in minutes and tenths of a minute, and this product added (subtracted if the temperature was *falling* at the time a) to the thermometer reading taken at the time a. The rate r_3 is to be multiplied by the time $c-b$ and this product added (subtracted if the temperature was *rising* at the time c and later) to the thermometer reading taken at the time c. The difference of the two thermometer readings thus corrected, provided the corrections from the certificate have already been applied, gives the total rise of temperature due to the combustion. This multiplied by the water equivalent of the calorimeter gives the total amount of heat liberated. This result, corrected for the heats of formation of HNO_3 and H_2SO_4 observed and for the heat of combustion of the firing wire, when that is included, is to be divided by the weight of the charge to find the heat of combustion in calories per gram. Calories per gram multiplied by 1.8 give the British thermal units per pound. (See example.)

The permissible differences in duplicate determinations are as follows:

	PER CENT.
Same analyst	0.3
Different analysts	0.5

In practice, the time $b-a$ will be found so nearly constant for a given calorimeter with the usual amounts of fuel that b need be determined only occasionally.

The results should be reduced to calories per gram or British thermal units per pound of *dry coal*, the moisture being determined upon a sample taken from the bottle at about the same time as the combustion sample is taken.

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[1] When the temperature rise is not approximately known beforehand, it is only necessary to take thermometer readings at 40, 50, 60 seconds (and possibly 70 seconds with some calorimeters) after firing, and from these observations to find when the temperature rise had reached 60 per cent of the total. Thus, if the temperature at firing was 2°.135, at 40 seconds 3°.05, at 50 seconds 3°.92, at 60 seconds 4°.16, and the final temperature was 4°.200, the total rise was 2°.07; 60 per cent of it was 1°.24. The temperature to be observed was then $2.^\circ 14+1^\circ.24=3^\circ.38$. Referring to the observations at 40 and 50 seconds, the temperatures were respectively 3.05 and 3°.92. The time corresponding to the temperature of 3°.38 was therefore

$$40+\frac{3.38-3.05}{3.92-3.05}\times 10=44 \text{ seconds.}$$

EXAMPLE.

OBSERVATIONS.

Water equivalent = 2550 g.
Weight of charge = 1.0535 g.
Approximate rise of temperature expected = 3°.2
60 per cent of approximate rise = 1°.9

Time.	Thermometer Readings.	Corrected Temperature (or corrected Beckmann thermometer readings).
10–21	15°.244 Thermometer corrections taken from the certificate.	
22	.250	
23	.255	
24	.261	
25	.266	
(*a*) 26	.272	15°.276
	Charge fired	
(*b*) 27.2	17°.2[d]	
31	18°.500	18°.497
32	.498	
33 ·	.497	
34	.498	
35	.494	
36	.493	

COMPUTATION.

$r_1 = 0^\circ.028 \div 5 = 0^\circ.0056$ per minute. $b-a=1.2$ minutes.

The corrected initial temperature is

$15^\circ.276 + 0^\circ.0056 \times 1.2 = 15^\circ.283$

$r_2 = 0^\circ.007 \div 5 = 0^\circ.0014$ per minute; $c-b=3.8$ minutes

The corrected final temperature is

$18^\circ.497 + 0.0014 \times 3.8$	$= 18^\circ.502$	
Total rise $18^\circ.502 - 15^\circ.283$	$= 3^\circ.219$	
Total calories 2550×3.219	=	8209
Titration, etc		−7
Calories from 1.0535 g. coal		8202
Calories per gram	7785	
or British thermal units per pound	14013	

The results obtained by the above method of computation and determination is the total heat of combustion at constant volume, with the water in the products of combustion condensed to liquid at the temperature of the calorimeter, that is, about 20 to 35° C.

Net heat of combustion at 20°, shall refer to results corrected for latent heat of vaporization, as follows:

Total heat of combustion in B. t. u. − 1040 (hydrogen × 9) = net heat of combustion in B. t. u. per pound.

Also

Total heat of combustion in calories − 580 (hydrogen × 9) = net heat of combustion in calories per gram.

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[d] The initial temperature is 15°.27; 60 per cent of the expected rise is 1°.9. The reading to observe is then 17°.2.

NOTES.

For anthracite, coke and coal of high ash content, which do not readily burn completely, the following procedure is recommended:

The inside of the crucible is lined completely with ignited asbestos in a thin layer pressed well down into the angles. The coal is then sprinkled evenly over the surface of the asbestos. Otherwise the procedure is as previously described.

The method of computing the "cooling correction" described in Technical Paper No. 8, Bureau of Mines, pages 28 to 32, may also be used.

STANDARD METHODS
OF
LABORATORY SAMPLING AND ANALYSIS OF COKE

Serial Designation: D 37 – 21.

These methods are issued under the fixed designation D 37; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1916; Adopted in Amended Form, 1918; Revised, 1921.

DETERMINATION OF TOTAL MOISTURE AND PREPARATION OF LABORATORY SAMPLES.

Apparatus.

Galvanized-Iron Pans 24 by 24 by 4 in. Deep.—For total moisture determination.

Balance or Solution Scale.—For weighing the galvanized-iron pans with samples. It should have a capacity of 10 kg. and be sensitive to 1 g.

Jaw Crusher.—For crushing coarse samples to pass a 4-mesh sieve.

Roll Crusher.—For reducing the 4-mesh product to 10-mesh.

Abbé Ball Mill or Hard-Steel Diamond Mortar.—For reducing the 10-mesh product to 60-mesh. The porcelain jars for the ball mill should be approximately 9 in. in diameter and 10 in. high. The flint pebbles should be smooth, hard and well rounded.

A Large Riffle Sampler, with $\frac{5}{8}$ or $\frac{3}{4}$-in. Divisions.—For reducing the 4-mesh sample to 5 lb. (Fig. 1).

A Small Riffle Sampler, with $\frac{1}{4}$ or $\frac{3}{8}$-in. Divisions.—For dividing down the 10 and 60-mesh material to a laboratory sample.

An 8-in. No. 60 Bureau of Standards Standard Screen Scale Sieve with Cover and Receiver.

Containers for Shipment to Laboratory.—Samples in which the moisture content is important should always be shipped in moisture-tight containers. A galvanized-iron or tin can with air-tight friction top or a screw top which is sealed with a rubber gasket and adhesive tape is best adapted to this purpose. Glass fruit jars sealed with rubber gaskets may be used, but require very careful packing to avoid breakage in transit. Samples in which the moisture content is of no importance need no special protection from loss of moisture.

Oven, Stove or Hot Plate.—For drying coke samples in the determination of total moisture. If an oven is used it should have openings provided for natural ventilation and should be capable of being regulated between 104 and 200° C. If the coke is dried on a stove or hot plate a thermometer should be placed in it, and care exercised that the temperature does not exceed 200° C. at any point in the pan of coke.

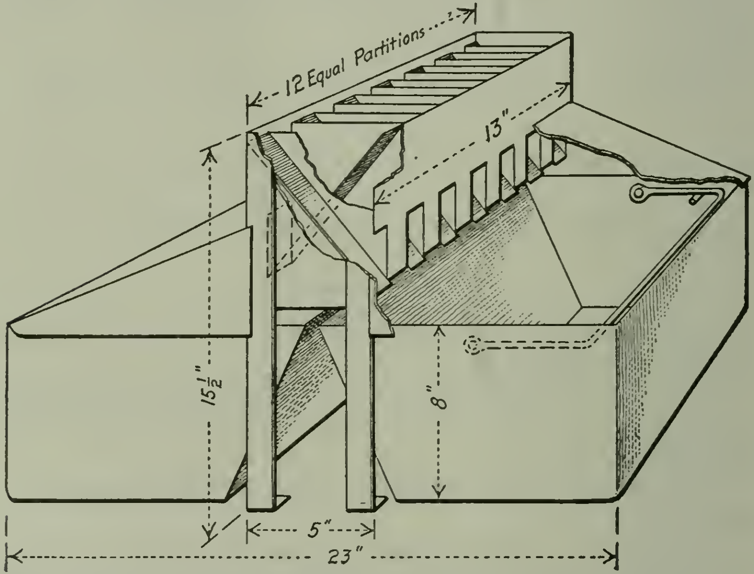

FIG. 1.—Riffle Sampler. (*Bulletin No. 9*, Geological Survey of Ohio, p. 213.)

METHOD.

Total Moisture Determination.—Dry the entire sample received at the laboratory without any preliminary crushing to constant weight at a temperature of not less than 104 nor more than 200° C.[1]

Calculate the loss in weight to percentage of moisture, which shall constitute the total moisture in the coke as received at the laboratory.

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[1] Experiments made at the Bureau of Mines have shown that results checking within 0.5 per cent are obtained between these temperature limits.

The allowable difference in duplicate determinations by the same analyst is 0.5 per cent.

Reduction of Sample.—Crush the dried sample mechanically with a jaw or roll crusher, or by hand on a chilled iron or hard-steel plate by impact of a hard bar or sledge, avoiding all rubbing action, as otherwise the ash content will be materially increased by the addition of iron from the sampling apparatus, even though hardened iron or steel is used. Continue the crushing until all the sample passes through a 4-mesh screen, mix and quarter this to not less than 5 lb.; again crush the 5-lb. sample to a fineness of 10-mesh; mix and quarter to 400 g. Transfer this 400-g. portion to the porcelain jar of an Abbé ball mill and pulverize to 60-mesh. When pulverization is complete, pour the contents of the jar on a ½-in. screen and separate the sample from the pebbles by shaking the screen. Reduce the quantity of sample by quartering or riffling to about 50 g. Pass the entire 50-g. portion through a 60-mesh sieve, pulverizing any coarse particles in a diamond mortar, and mix with remainder of sample, preserving the sample for analysis in a rubber-stoppered glass bottle.

In case a ball mill is not available for fine grinding, quarter the 5-lb. 10-mesh sample to 200 g. and pulverize to 60-mesh, by impact in a hard-steel diamond mortar. The use of rubbing surfaces such as a disk pulverizer or a bucking board is never permissible for grinding coke.

NOTES.

The accuracy of the method of preparing laboratory samples should be checked frequently by resampling the rejected portions and preparing a duplicate sample. The ash in the two samples should not differ more than 0.4 per cent.

DETERMINATION OF MOISTURE.

APPARATUS.

Moisture Oven.—An ordinary drying oven with openings for natural air circulation and capable of temperature regulation between limits of 104 and 110° C. may be used.

Capsules with Covers.—A convenient form, which allows the ash determination to be made on the same sample, is a

No. 2 porcelain capsule, $\frac{7}{8}$ in. deep and $1\frac{3}{4}$ in. in diameter. This is to be used with a well-fitting flat aluminum cover, illustrated in Fig. 2.

Platinum crucibles or glass capsules with ground-glass caps may also be used. They should be as shallow as possible, consistent with convenient handling.

METHOD.

Heat the empty capsules under the conditions at which the coke is to be dried, stopper or cover, cool over concentrated H_2SO_4, sp. gr. 1.84, for 30 minutes, and weigh. Transfer to the capsule an amount slightly in excess of 1 g. and bring to exactly 1 g. in weight (±0.5 mg.) by quickly removing the excess weight of coke with a spatula.

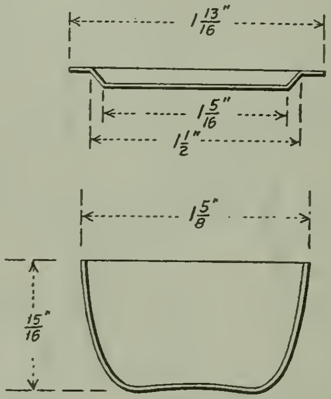

FIG. 2.—Porcelain Capsule with Flat Aluminum Cover.

Place the capsules, uncovered, in a pre-heated oven (at 104 to 110° C.). Close the oven at once and heat for 1 hour. Then open the oven, cover the capsules quickly and place them in a desiccator over concentrated H_2SO_4. When cool, weigh.

The percentage moisture in the 60-mesh sample shall be used to calculate the other results to a dry basis.

The permissible differences in duplicate determinations are as follows:

	PER CENT.
Same analyst	0.2
Different analysts	0.3

DETERMINATION OF ASH.

APPARATUS.

Gas or Electric Muffle Furnace or Meker Burner.—The muffle should have good air circulation and be capable of having its temperature regulated to not exceed 950° C.

Porcelain Capsules.—No. 2 porcelain capsules, $\frac{7}{8}$ in. deep and $1\frac{3}{4}$ in. in diameter, or similar shallow dishes or platinum crucibles.

METHOD.

Place the capsules containing the dried coke from the moisture determination in a muffle furnace or over a burner, and heat to redness at such a rate as to avoid mechanical loss. Finish the ignition to constant weight (± 0.001 g.) at a temperature not exceeding 950° C. Cool in a desiccator and weigh.

The permissible differences in duplicate determinations are as follows:

	PER CENT.
Same analyst	0.2
Different analysts	0.3

NOTES.

Before replacing the capsules in the muffle for ignition to constant weight the ash should be stirred with a platinum or nichrome wire. Stirring once or twice before the first weighing hastens complete ignition.

Test the ash for unburned carbon, by moistening it with alcohol; any carbon remaining will show as black particles.

DETERMINATION OF VOLATILE MATTER.

APPARATUS.

Platinum Crucible with Tightly Fitting Cover.—The crucible should be of 10-cc. capacity, with capsule cover having thin flexible sides fitting down into crucible. Or the double-crucible method may be used, in which the sample is placed in a 10 or 20-cc. platinum crucible, which is then covered with another crucible of such a size that it will fit closely to the sides of the outer crucible, and its bottom will rest $\frac{1}{3}$ to $\frac{1}{2}$ in. above the bottom of the outer crucible.

Vertical Electric Tube Furnace; or a Gas or Electrically Heated Muffle Furnace.—The furnace may be of the form shown in Fig. 3. It is to be regulated to maintain a temperature of

950° C. (±20° C.) in the crucible, as shown by a thermocouple kept in the furnace. A Meker burner may be used, if satisfactory to both parties to the contract.

METHOD.

Weigh 1 g. of the coke in a weighed 10-cc. platinum crunible, close with capsule cover and place on platinum or cichrome-wire supports in the furnace chamber, which must be at a temperature of 950° C. (±20° C.). After the crucible has been heated 2 or 3 minutes tap the cover lightly to more perfectly seal the crucible and thus guard against the admission of air. After heating exactly 7 minutes, remove the crucible from the furnace and, without disturbing the cover, allow it to cool in a desiccator. Weigh as soon as cold. The loss of weight minus moisture equals the volatile matter.

The permissible differences in duplicate determinations are as follows:

	PER CENT.
Same analyst	0.2
Different analysts	0.4

ALTERNATE METHOD, USING MEKER BURNER.

Weigh 1 g. of the coke in a weighed 10 or 20-cc. platinum crucible, close with capsule cover or another crucible as described above under "apparatus," and place in the flame of a No. 4 Meker burner, having approximately an outside diameter at the top of 25 mm. and giving a flame not less than 15 cm. high. The temperature should be 950° C. (± 20° C.), as determined by placing a thermocouple through the perforated cover, which for this purpose may be of nickel or asbestos. The junction of the couple should be placed in contact with the center of the bottom of the crucible; or the temperature may be indicated by the fusion of pure K_2CrO_4 in the covered crucible (fusion of K_2CrO_4, 940° C.). The crucible is placed in the flame about 1 cm. above the top of the burner and the heating is continued 7 minutes. Where the gas pressure is variable it is well to use a U-tube attachment to the burner.

DETERMINATION OF FIXED CARBON.

Compute fixed carbon as follows:

100 − (moisture + ash + volatile matter) = percentage of fixed carbon.

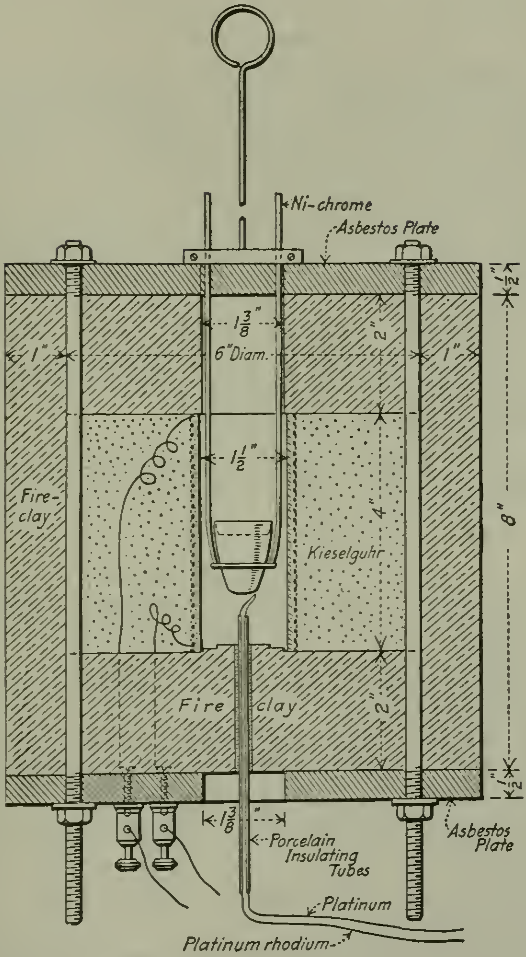

FIG. 3.—Electric Tube Furnace for Determining Volatile Matter. For 110-volt Alternating Current, 60 ft. of Nichrome Wire, No. 17 B. & S. gage will give the required temperature. The temperature must be controlled by an external resistance. (*Technical Paper No. 76*, Bureau of Mines, p. 21.)

DETERMINATION OF SULFUR BY THE ESCHKA METHOD.

APPARATUS.

Gas or Electric Muffle Furnace, or Burners.—For igniting coke with the Eschka mixture and for igniting the $BaSO_4$.

Porcelain, Silica, or Platinum Crucibles or Capsules.—For igniting coke with the Eschka mixture.

No. 1 porcelain capsule, 1 in. deep and 2 in. in diameter. This capsule, because of its shallow form, presents more surface for oxidation and is more convenient to handle than the ordinary form of crucible.

No. 1 porcelain crucibles, shallow form, and platinum crucibles of similar size may be used. Somewhat more time is required to burn out the coke owing to the deeper form, than with the shallow capsules described above.

No. 0 or 00 porcelain crucibles, or platinum, alundum or silica crucibles of similar size are to be used for igniting the $BaSO_4$.

SOLUTIONS AND REAGENTS.

Barium Chloride.—Dissolve 100 g. of $BaCl_2 \cdot 2H_2O$ in 1000 cc. of distilled water.

Saturated Bromine Water.—Add an excess of bromine to 1000 cc. of distilled water.

Eschka Mixture.—Thoroughly mix 2 parts (by weight) of light calcined MgO and 1 part of anhydrous Na_2CO_3. Both materials should be free as possible from sulfur.

Methyl Orange.—Dissolve 0.02 g. in 100 cc. of hot distilled water and filter.

Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20, and 500 cc. of distilled water.

Normal Hydrochloric Acid.—Dilute 80 cc. of HCl, sp. gr. 1.20, to 1 liter with distilled water.

Sodium Carbonate.—A saturated solution, approximately 60 g. of crystallized or 22 g. of anhydrous Na_2CO_3 in 100 cc. of distilled water.

Sodium-Hydroxide Solution.—Dissolve 100 g. of NaOH in 1 liter of distilled water. This solution may be used in place of the Na_2CO_3 solution.

METHOD.

Preparation of Sample and Mixture.—Thoroughly mix on glazed paper, 1 g. of 60-mesh coke and 3 g. of Eschka mixture. Transfer to a No. 1 porcelain capsule, 1 in. deep and 2 in. in diameter, or a No. 1 porcelain crucible or platinum crucible of similar size, and cover with about 1 g. of Eschka mixture.

Ignition.—On account of the amount of sulfur contained in artificial gas, the crucible shall be heated over an alcohol, gasoline or natural gas flame, as in procedure (*a*) below, or in a gas or electrically heated muffle, as in procedure (*b*) below. The use of artificial gas for heating the coke and Eschka mixture is permissible only when crucibles are heated in a muffle.

(*a*) Heat the crucible, placed in a slanting position on a triangle, over a low flame at first, then gradually increase the temperature and stir occasionally until all the black particles disappear, which is an indication of the completeness of the procedure.

(*b*) Place the crucible in a warm muffle and gradually raise the temperature to 870–925° C. (cherry-red heat) in about ½ hour. Maintain this maximum temperature until on stirring all black particles have disappeared.

Subsequent Treatment.—Remove and empty the contents into a 200-cc. beaker and digest with 100 cc. of hot water for ½ to ¾ hour, with occasional stirring. Filter and wash the insoluble matter by decantation. After several washings in this manner, transfer the insoluble matter to the filter and wash 5 times, keeping the mixture well agitated. Treat the filtrate, amounting to about 250 cc., with 10 to 20 cc. of saturated bromine water, make slightly acid with HCl and boil to expel the liberated bromine. Make just neutral to methyl orange with NaOH or Na_2CO_3 solution, then add 1 cc. of normal HCl. Boil again and add slowly from a pipette with constant stirring 10 cc. of a 10-per-cent solution of $BaCl_2 \cdot 2H_2O$. Continue boiling for 15 minutes and allow to stand for at least 2 hours, or preferably overnight, at a temperature just below boiling. Filter through an ashless filter paper and wash with hot distilled water until an $AgNO_3$ solution shows no precipitate with a drop of the filtrate Place the wet filter containing the precipitate of $BaSO_4$ in a weighted platinum, porcelain, silica or alundum crucible, allowing a free access of air by folding the paper over the precipitate loosely to prevent spattering. Smoke the paper off gradually and at no time allow it to burn with flame. After the paper is practically consumed raise the temperature to approximately 925° C. and heat to constant weight.

The residue of MgO, etc., after leaching, should be dissolved in HCl and tested with great care for sulfur. When an appreciable amount is found this should be determined quantitatively. The amount of sulfur retained is by no means a negligible quantity.[1]

Blanks and Corrections.—In all cases a correction must be applied either (1) by running a blank exactly as described above, using the same amounts of all reagents that were employed in the regular determination, or, more surely, (2) by determining a known amount of sulfate added to a solution of the reagents after these have been put through the prescribed series of operations. If this latter procedure is adopted and carried out, say, once a week or whenever a new supply of a reagent must be used, and for a series of solutions covering the range of sulfur content likely to be met with in coke, it is only necessary to add or to subtract from the weight of $BaSO_4$ obtained from a coke whatever deficiency or excess may have been found in the appropriate "check" in order to obtain a result that is more certain to be correct than if a "blank" correction as determined by the former procedure is applied. This is due to the fact that the solubility error for $BaSO_4$ is, for the amounts of sulfur in question and the conditions of precipitation prescribed, probably the largest one to be considered. $BaSO_4$ is soluble[2] in acids and even in pure water, and the solubility limit is reached almost immediately on contact with the solvent. Hence, in the event of using reagents of very superior quality or of exercising more than ordinary precautions, there may be no apparent "blank," because the solubility limit of the solution for $BaSO_4$ has not been reached, or at any rate not exceeded.

$$(\text{Weight of } BaSO_4 - \text{blank}) \times 13.73 = \text{percentage of sulfur.}$$

The permissible differences in duplicate determinations are as follows:

	PER CENT.
Same analyst	0.03
Different analysts	0.05

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[1] *Journal*, Am. Chem. Soc., Vol. 21, p. 1128 (1899).

[2] *Journal*, Am. Chem. Soc., Vol. 32, p. 588 (1910); Vol. 33, p. 829 (1911).

DETERMINATION OF PHOSPHORUS IN ASH.

Method No. 1. To Cover all Cases.—To the ash from 5 g. of coke in a platinum capsule is added 10 cc. of HNO_3 and 3 to 5 cc. of HF. The liquid is evaporated and the residue fused with 3 g. of Na_2CO_3. If unburned carbon is present 0.2 g. of $NaNO_3$ is mixed with carbonate. The melt is leached with water and the solution filtered. The residue is ignited, fused with Na_2CO_3 alone, the melt leached and the solution filtered. The combined filtrates, held in a flask, are just acidified with HNO_3 and concentrated to a volume of 100 cc. To the solution, brought to a temperature of 85° C., is added 50 cc. of molybdate solution and the flask is shaken for 10 minutes. If the precipitate does not form promptly and subside rapidly, add enough NH_4NO_3 to cause it to do so. The precipitate is washed six times, or until free from acid, with a 2-per-cent solution of KNO_3, then returned to the flask and titrated with standard NaOH solution. The alkali solution may well be made equal to 0.00025 g. of phosphorus per cubic centimeter, or 0.005 per cent, for a 5-g. sample of coke, and is 0.995 of one-fifth normal.[1] Or the phosphorus in the precipitate is determined by reduction and titration of the molybdenum with permanganate.

Note on Method No. 1.—The advantage of the use of HF in the initial attack of the ash lies in the resulting removal of silica. Fusion with alkali carbonate is necessary for the elimination of titanium, which if present and not removed will contaminate the phospho-molybdate and is said to sometimes retard its precipitation.

Method No. 2.—When titanium is so low as to offer no objection, the ash is decomposed as under method No. 1, but evaporation is carried only to a volume of about 5 cc. The solution is diluted with water to 30 cc., boiled and filtered. If the washings are turbid they are passed again through the filter. The residue is ignited in a platinum crucible, fused with a little Na_2CO_3, the melt dissolved in HNO_3 and its solution, if clear, added to the main one. If not clear it is filtered. The subsequent procedure is as under method No. 1. The fusion of the residue may be dispensed with in routine work on a given coke if it is certain that is free from phosphorus.

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[1] Ulmann and Buch, *Chemical Engineer*, Vol. 10, p. 130 (1909).

STANDARD SPECIFICATIONS
FOR
YELLOW-PINE BRIDGE AND TRESTLE TIMBERS.

To be Applied to Solid Members and not to Composite Members.

Serial Designation: D 10 – 15.

These specifications are issued under the fixed designation D 10; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1910; Revised, 1915.

I. GENERAL REQUIREMENTS.

1. Except as noted, all timber shall be cut from sound trees and sawed standard size; close-grained and solid; free from defects such as injurious ring shakes and crooked grain; unsound knots; knots in groups; decay; large pitch pockets, or other defects that will materially impair its strength.

Dense Southern Yellow Pine.

2. (*a*) Dense southern yellow pine shall show on one end or the other an average of at least six annual rings per inch and at least one-third summer wood, all as measured over the third, fourth, and fifth inches on a radial line from the pith. Wide-ringed material excluded by this rule will be acceptable, provided that the amount of summer wood as above measured shall be at least one-half.

(*b*) The contrast in color between summer wood and spring wood shall be sharp and the summer wood shall be dark in color, except in pieces having considerably above the minimum requirement for summer wood.

(*c*) In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over 3 in. on an approximate radial line beginning at the edge nearest the pith in timbers over 3 in. in thickness and on the second inch (on the piece) nearest to the pith in timbers 3 in. or less in thickness.

(*d*) In dimension material containing the pith but not a 5-in. radial line, which is less than 2 by 8 in. in section or less than 8 in. in width, that does not show over 16 sq. in. on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a 5-in. radial line the inspection shall apply to the three inches farthest from the pith.

(*e*) The radial line chosen shall be representative. In case of disagreement between purchaser and seller the average summer wood and number of rings shall be the average of the two radial lines chosen.

Sound Southern Yellow Pine.

3. Sound southern yellow pine shall include pieces of southern pine without any ring or summer-wood requirement.

Standard Size of Sawed Timber.

4. Rough timbers when sawed to standard size, shall mean that they shall not be over ¼ in. scant from actual size specified. For instance, a 12 by 12-in. timber shall measure not less than 11¾ by 11¾ in.

Standard Dressing of Sawed Timber.

5. Standard dressing means that not more than ¼ in. shall be allowed for dressing each surface. For instance, a 12 by 12-in. timber shall, after dressing four sides, not measure less than 11½ by 11½ in.

II. STRINGERS.

Stringers.

6. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show not less than 80 per cent of heart on each of the four sides, measured across the sides anywhere in the length of the piece; loose knots, or knots greater than 1½ in. in diameter, will not be permitted at points within 4 in. of the edges of the piece.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged, except it may have 1 in. wane on one corner. Knots shall not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur. Ring shakes extending not over one-eighth of the length of the piece are admissible.

III. CAPS AND SILLS.

Caps and Sills.

7. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show 85 per cent of heart on each of the four sides, measured across the sides anywhere in the length of the piece, and shall be free from knots over 2½ in. in diameter. Knots shall not be in groups.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged, except it may have 1 in. wane on one corner, or ½ in. wane on two corners. Knots shall not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur. Ring shakes shall not extend over one-eighth of the length of the piece.

IV. POSTS.

Posts.

8. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show not less than 75 per cent of heart, measured across the face anywhere on the length of the piece, and shall be free from knots over 2½ in. in diameter. Knots shall not be in groups.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged, except it may have 1 in. wane on one corner, or ½ in. wane on two corners. Knots shall not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur. Ring shakes shall not extend over one-eighth of the length of the piece.

V. LONGITUDINAL STRUTS OR GIRTS.

Longitudinal Struts or Girts.

9. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show one face all heart; the other face and two sides shall show not less than 85 per cent of heart, measured across the face or side anywhere in the piece, and shall be free from knots 1½ in. or over in diameter.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged and sound, and shall be free from knots 1½ in. or over in diameter.

VI. LONGITUDINAL X-BRACES, SASH BRACES AND SWAY BRACES.

Longitudinal X-Braces, Sash Braces and Sway Braces.

10. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show not less than 80 per cent of heart on two faces and four square edges, and shall be free from knots over 1½ in. in diameter.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged and sound, and shall be free from knots 2½ in. or over in diameter.

STANDARD SPECIFICATIONS
FOR
SOUTHERN YELLOW-PINE TIMBER TO BE CREOSOTED.

Serial Designation: D 24 – 20.

These specifications are issued under the fixed designation D 24; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1915; ADOPTED, 1920.

General Requirements. 1. The specifications as to strength shall agree with the requirements of the Standard Definitions of Terms Relating to Structural Timber (Serial Designation: D 9) of the American Society for Testing Materials.

Sapwood. 2. All pieces, except as specified in Section 6, shall show at least 30 per cent sapwood in cross-section. This is based on a minimum treatment of 12 lb. of creosote per cubic foot of timber.

Bridge Stringers. 3. In bridge stringers knots greater than 1½ in. in diameter shall be at least 4 in. from the edges of the stick. There shall be no knots more than 4 in. in greatest diameter in any part of the stick.

Caps and Sills 4. Caps, sills, posts and sawed poles shall be free from knots more than 2½ in. in diameter.

Bracing. 5. Longitudinal bracing, cross-arms and similar pieces having small cross-section shall have no knots more than 1 in. in diameter.

Track Ties. 6. Track ties shall show at least 20 per cent sapwood in cross-section. This is based on a minimum full-cell treatment of 8 lb. of creosote per cubic foot of timber.

STANDARD SPECIFICATIONS
FOR
SOUTHERN YELLOW-PINE PILES AND POLES TO BE CREOSOTED.

Serial Designation: D 25 – 20.

These specifications are issued under the fixed designation D 25; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1915; Adopted, 1920.

General Requirements. 1. The specifications as to strength shall agree with the requirements of the Standard Definitions of Terms Relating to Structural Timber (Serial Designation: D 9) of the American Society for Testing Materials.

Sapwood. 2. All piles or telegraph poles shall show 40 per cent sapwood in cross-section, or there shall be a ring of sapwood not less than 1 in. in thickness all around the heartwood.

Quality. 3. (*a*) Piles and poles shall be cut from sound live trees, of straight grain and regular taper; without crooks exceeding one-fourth the diameter of the stick at middle of crook when peeled. They shall be free from rot, red heart, holes or rotten knots, shakes and felling checks.

(*b*) All piles and poles shall have the bark and inner skin carefully removed when the tree is felled; all limbs and knots trimmed flush and butts cut square.

Minimum Diameter. 4. The minimum diameter of piles after peeling shall be as follows:

Length	Butts, in.	Tops, in.
36 ft. and under	14	10
38 ft. and under 50 ft.	14	9
50 ft. and over	15	9

No pile with butt diameter over 18 in., nor top diameter over 13½ in., will be accepted. The length of each pile shall be legibly marked on the butt with white or black paint.

STANDARD SPECIFICATIONS
FOR
WOODEN PAVING BLOCKS FOR EXPOSED PAVEMENTS.

Serial Designation: D 52 – 20.

These specifications are issued under the fixed designation D 52; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1918; Adopted in Amended Form, 1920.

Material Covered.

1. These specifications cover wooden paving blocks for pavements exposed to alternate wet and dry conditions, as distinguished from pavements which are used under cover and protected from atmospheric influences.

I. TIMBER.

Kind of Timber

2. The wood, which shall be treated, shall be Southern yellow pine, Douglas fir, tamarack, Norway pine, hemlock, or black gum. Only one kind of wood shall be used in any one contract. The blocks shall be sound, and shall be well manufactured, square-butted, square-edged, free from unsound, loose or hollow knots, knot holes, worm holes, and other defects such as shakes, checks, etc., that would be detrimental to the blocks.

Quality of Timber.

3. The number of annual rings in the one inch which begins two inches from the pith of the block shall not be less than six, measured radially; provided, however, that blocks containing between five and six rings in this inch shall be accepted if they contain 33⅓ per cent or more summerwood. In case the block does not contain the pith, the one inch to be used shall begin one inch away from the ring which is nearest to the heart of the block. The blocks in each charge shall contain an average of at least 70 per cent of heart wood. No one block shall be accepted that contains less than 50 per cent of heart wood.

Size of Blocks.

4. The blocks shall be from 5 to 10 in. long, but should preferably average two times the depth; they shall be .... in. in depth.[1] They may be from 3 to 4 in. in width, but in any

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[1] It is recommended that blocks 4 in. in depth be used for streets with very heavy traffic, and blocks 3½ in. in depth for streets with moderate traffic. For streets with light traffic blocks 3 in. in depth may be used, but where 3-in. blocks are used no block shall be longer than 8 in.

one city block all of them shall be of uniform width. A variation of $\frac{1}{16}$ in. shall be allowed in the depth and $\frac{1}{8}$ in. in the width of the blocks from that specified. In all cases the width shall be greater or less than the depth by at least $\frac{1}{4}$ in.

II. TREATMENT.

Treatment.

5. The timber may be either air-seasoned or green, but should preferably be treated within three months from the time it is sawed. Green timber and seasoned timber shall not, however, be treated together in the same charge. The blocks shall be treated in an air-tight cylinder with the preservative specified by the purchaser. In all cases, whether thoroughly air-seasoned or green, they shall first be subjected to live steam at a temperature between 220 and 240° F.[1] for not less than 2 hours nor more than 4 hours, at the discretion of the treating plant operator, after which they shall be subjected to a vacuum of not less than 22 in. held for at least one hour. While the vacuum is still on, the preservative oil, heated to a temperature of between 180 and 220° F., shall be run in until the cylinder is completely filled, care being taken that no air is admitted. Pressure shall then be gradually applied not to exceed 50 lb. at the end of the first hour nor 100 lb. at the end of the second hour, and then maintained at not less than 100 lb. nor more than 150 lb. until the wood has absorbed the required amount of oil.[2]

After this a supplemental vacuum, in which the maximum intensity reached is at least 20 in. and the time the vacuum is applied not less than 30 minutes, shall be applied. If desired, this vacuum may be followed by a short steaming period.

Penetration of Preservative.

6. In any charge blocks shall contain at least 16 lb. of water-free oil per cubic foot of wood at the completion of the treatment. The blocks after treatment shall show satisfactory penetration of the preservative, and in all cases the oil shall be diffused throughout the sap wood. To determine this, at least 25 blocks shall be selected from various parts of each charge and sawed in half perpendicular to the fibers through the center, and if more than one of these blocks show untreated sap wood, the charge shall be re-treated. After re-treating, the charge shall be again subjected to a similar inspection.

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[1] In no case shall a steam pressure of 20 lb. per sq. in. be exceeded.

[2] This treatment is recommended for yellow pine only. It is probably also suited to Norway pine, hemlock, black gum and tamarack, but not to Douglas fir. Further recommendations on the treatment of these species are reserved for the future.

Handling Blocks After Treatment. 7. Blocks shall preferably be laid in the street as soon as possible after being treated. If they cannot be laid immediately, provision shall be made to prevent them from drying out by stacking in close piles and covering them, and, if possible, by sprinkling them thoroughly at intervals. In any case, where they are not laid as soon as they are received on the street, they shall be well sprinkled about two days before being laid, under the direction of the purchaser. It is important to have the wood sufficiently wet to be swelled to its maximum size before it is laid.

III. PRESERVATIVE.

Preservative 8. The preservative used shall be coal-tar paving oil or distillate oil, as specified by the purchaser.

IV. INSPECTION.

Inspection at Plant. 9. All material herein specified and processes used in the manufacture of the blocks therefrom shall be subject to inspection, acceptance, or rejection at the plant of the manufacturer, which shall be equipped with all the necessary gages, appliances, and facilities to enable the inspector to satisfy himself that the requirements of the specifications are being fulfilled.

Inspection at Street. 10. The purchaser shall have the further right to inspect the blocks after delivery upon the street, for the purpose of rejecting any blocks that do not meet these specifications; except that the plant inspections shall be final with respect to the kind of wood, number of rings per inch, oil, and treatment.

STANDARD METHODS
OF
SAMPLING AND ANALYSIS OF CREOSOTE OIL.

Serial Designation: D 38 – 18.

These methods are issued under the fixed designation D 38; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1915; ADOPTED, 1917; REVISED, 1918.

A. SAMPLING.

Continuous-Drip Sample.

1. Wherever the oil is being loaded or discharged by means of a pump the following method shall be used:

A ½-in. sampling pipe shall be inserted in the line through which the oil is being pumped, on the discharge side of the pump, preferably in a rising section of the pipe line. This sampling pipe shall extend one-half way to the center of the main pipe and with the inner open end of the sampling pipe turned at an angle of 90 deg. and facing the flow of the liquid. This pipe shall be provided with a plug cock and shall discharge into a receiver of 50 to 100 gal. capacity. The plug cock shall be so adjusted that, with a steady continuous flow of the oil, the receiver shall be filled in the time required to pump the entire shipment. The receiver shall be provided with a steam coil sufficient to keep the contents at a temperature not exceeding 120° F. Immediately upon completion of the pumping, the contents of the receiver shall be very thoroughly agitated and a duplicate 1-qt. sample taken immediately for the test. The amount of the drip sample collected shall be not less than one gallon for each 1000 gal. of oil handled, except in the case of large boat shipments, where a maximum of 100 gal. is sufficient.

B. ANALYSIS.

WATER.

Apparatus.

2. (*a*) *Still.*—A vertical, cylindrical copper still, with removable flanged top and yoke, of the form and approximate dimensions shown in Fig. 1, shall be used.

(*b*) *Thermometer.*—The standard distillation thermometer, as specified under "Distillation," Section 9 (*e*), shall be used.

(*c*) *Condenser.*—A copper trough condenser shall be used, with straight-walled glass tube, having approximately the form and dimensions shown in Fig. 2.

(*d*) *Separatory Funnel.*—A separatory funnel of the form shown in Fig. 2 shall be used, having a total capacity of 120 cc., and the outlet graduated in fifths of a cubic centimeter.

Assembling Apparatus.

3. The apparatus shall be set up as shown in Fig. 2.

Water Test.

4. When any measurable amount of water is present in the distillate below 210° C. on testing in accordance with Part (*D*) on "Distillation," the oil and water in this fraction shall be separated, if possible, and measured separately. If more than 2 per cent of water is present, or if the water is apparently present to an extent in excess of 2 per cent, but an accurate separation is impossible, the percentage of water present shall be determined by the following method, and the water-free oil so obtained shall be used in the distillation test:

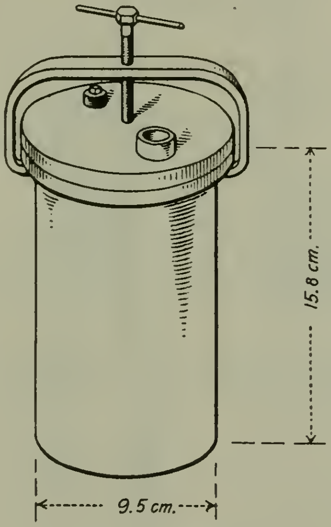

FIG. 1.—Copper Still.

Measure 200 cc. of oil in graduated cylinder, and pour into copper still, allowing the cylinder to drain into the still for several minutes. Attach lid and clamp, using a paper gasket slightly wet with oil around the flange of the still. Apply heat by means of the ring burner, which shall be placed just above the level of the oil in the still at the beginning of the test, and gradually lowered when most of the water has distilled over. Continue the distillation until the vapor temperature, indicated by the thermometer with the bulb opposite the offtake of the connecting tube, reaches 205° C. Collect distillate in separatory funnel. When the distillation is completed, and a clear separation of water and oil in the funnel has taken place, read the water by volume and draw off; and return any light oil distilled over with the water to the oil in the still. The dehydrated oil from the still shall be used for the distillation test.

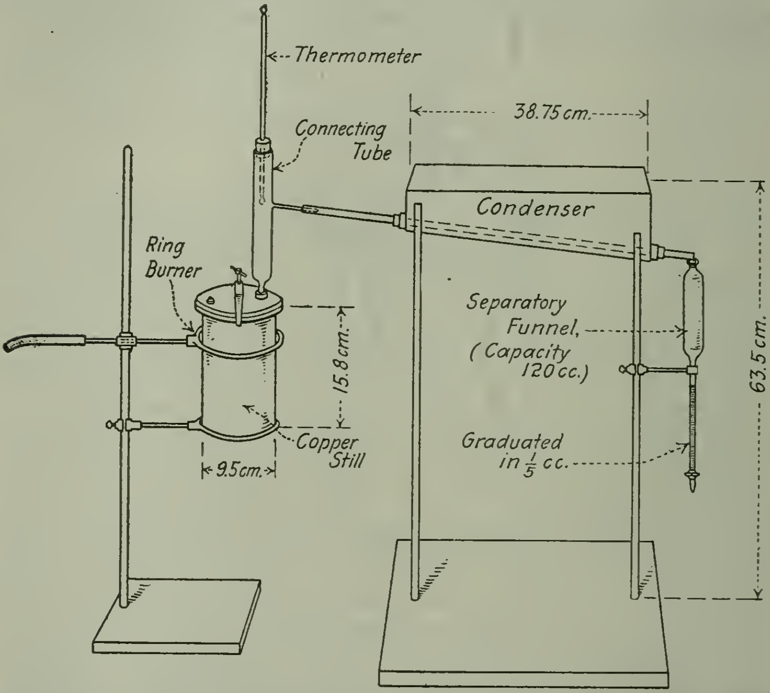

FIG. 2.—Assembled Apparatus for Water Test.

MATTER INSOLUBLE IN BENZOL.

Apparatus. 5. (*a*) *Extractor.*—The extractor may be of the form shown in Fig. 3, or any similar form in which the oil is subjected to direct washing by the boiling vapors of the solvent.

(*b*) *Filtering Medium.*—The filtering medium may be either two thicknesses of S. & S. No. 575 hardened filter paper, 15 cm.

in diameter, arranged in cup shape by folding symmetrically; or alundum thimbles, flat bottom, 30 x 80 RA 98. If filter papers are used, prior to using they shall be soaked in benzol to remove any grease, dried in a steam oven and kept in a desiccator until ready to be used. The filter-paper cup may be suspended in the extractor flask by a wire basket hung from two small hooks on the under surface of the metal cover of the flask. If the alundum thimble is used it may be supported by making two perforations in the top of the thimble, and suspending from the cover by German silver or platinum wires.

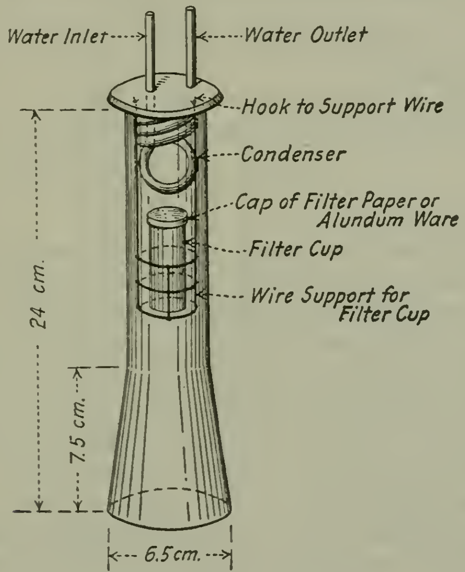

Fig. 3.—Extraction Flask.

"Insoluble in Benzol" Test.

6. Weigh 10 g. of dry oil in 100-cc. beaker. Add about 50 cc. of pure benzol and transfer at once to the filter cup. The filter cup or thimble is previously weighed, and the paper cup shall always be kept in a weighing bottle until ready for use. Wash out the beaker with benzol, passing all washings through the filter cup, and place latter at once in the extraction apparatus. Extractor shall contain a suitable quantity of pure benzol. Sufficient heat to boil the solvent shall be provided by means of an electric heater or a steam bath. Continue the extraction until the descending solvent is practically colorless, and remove the filter cup and dry in steam oven until all solvent

is driven off; cool in desiccator and weigh. The balance used for this purpose should be accurate to 0.5 mg.

SPECIFIC GRAVITY.

Apparatus.

7. (*a*) *Hydrometer.*—The hydrometer shall be of the form shown in Fig. 4. It shall have the following dimensions:

Length of stem.........	125	mm.;	permissible	variation,	12.5	mm.
“ “ bulb.........	105	“	“	“	10.5	“
“ “ scale.........	80	“	“	“	8.0	“
Diameter of stem.......	6	“	“	“	0.5	“
“ “ bulb.......	22	“	“	“	2.0	“

A set of two hydrometers with ranges 1.00 to 1.08 and 1.07 to 1.15 will suffice.

(*b*) *Cylinder.*—The cylinder shall be of the form shown in Fig. 5. It shall have the following dimensions:

Length................	300	mm.;	permissible	variation,	30	mm.
Diameter.............	32	“	“	“	3	“

Specific Gravity Test.

8. The oil shall be brought to a temperature of 38° C. (100° F.), and the determination shall be made at that temperature unless the oil is not entirely liquid at 38° C. In case the oil requires to be brought to a higher temperature than 38° C. in order to render it completely fluid, it shall be tested at the lowest temperature at which it is completely fluid, and a correction made by adding 0.0008 to the observed specific gravity for each degree Centigrade above 38° C. at which the test is made. This correction factor does not apply with equal accuracy to all oils, but serious error due to its use will be avoided if the foregoing precaution is observed, with respect to avoiding unnecessarily high temperature. Before taking the specific gravity the oil in the cylinder should be stirred thoroughly with a glass rod, and this rod when withdrawn from the liquid should show no solid particles at the instant of withdrawal. Care should be taken that the hydrometer does not touch the sides or bottom of the cylinder when the reading is taken, and that the oil surface is free from froth and bubbles.

DISTILLATION.

Apparatus.

9. (*a*) *Retort.*—This shall be a tubulated glass retort of the form and approximate dimensions shown in Fig. 6, with a capacity of 250 to 290 cc. The capacity shall be measured by placing the retort with the bottom of the bulb and the end of the

offtake in the same horizontal plane, and pouring water into the bulb through the tubulature until it overflows the offtake. The amount remaining in the bulb shall be considered its capacity.

(*b*) *Condenser Tube.*—The condenser tube shall be a suitable form of tapered glass tubing of the following dimensions:

Diameter of small end....	12.5 mm.;	permissible	variation,	1.5 mm.
" " large "	28.5 "	"	"	3.0 "
Length................	360.0 "	"	"	4.0 "

(*c*) *Shield.*—An abestos shield of the form and approximate dimensions shown in Fig. 7 shall be used to protect the retort from air currents and to prevent radiation. This may be covered with galvanized iron, as such an arrangement is more convenient and more permanent.

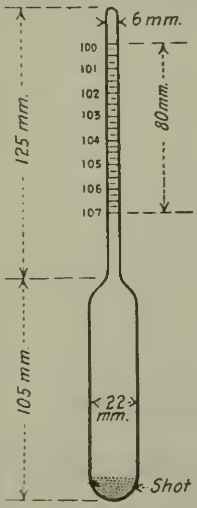

FIG. 4.—Hydrometer.

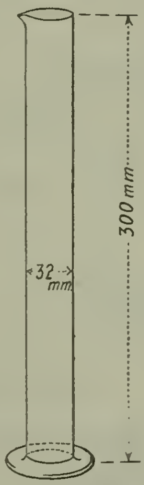

FIG. 5.—Cylinder.

(*d*) *Receivers.*—Erlenmeyer flasks of 50 to 100-cc. capacity are the most convenient form.

(*e*) *Thermometer.*—The thermometer shall conform to the following requirements:

The thermometer shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number and the letters "A. S. T. M. distillation."

The thermometer shall be graduated from 0 to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear-cut and distinct.

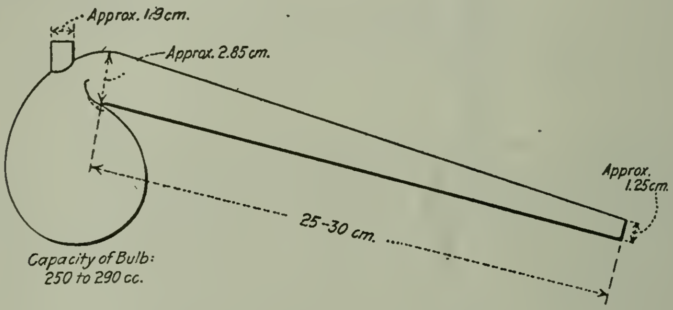

FIG. 6.—Retort for Distillation Test.

The thermometer shall conform to the following dimensions:

Total length, maximum	385	mm.	
Diameter of stem	7	"	; permissible variation, 0.5
Diameter of bulb, minimum	5	"	; and shall not exceed diameter of stem.
Length of bulb	12.5	"	; permissible variation, 2.5 mm.
Distance, 0° to bottom of bulb	30	"	; " " 5 "
Distance, 0 to 400°	295	"	; " " 10 "

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error shall not exceed the following:

From 0 to 200° C.	0°.5 C.
" 200 to 300° C.	1°.0 C.
" 300 to 375° C.	1°.5 C.

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water at the barometric pressure at the time of test and plunged into free flow of steam, the meniscus shall pass the point 10° C. below the boiling point of water in not more than six seconds.

Assembling Apparatus for Distillation Test

10. The retort shall be supported on a tripod or rings over two sheets of 20-mesh gauze, 6 in. square, as shown in Fig. 8. It shall be connected to the condenser tube by a tight cork joint. The thermometer shall be inserted through a cork in the tubulature with the bottom of the bulb ½ in. from the surface of the oil in the retort. The exact location of the thermometer bulb shall be determined by placing a vertical rule graduated in divisions not exceeding $\frac{1}{16}$ in. back of the retort when the latter is in position for the test, and sighting the level of the liquid and the point for the bottom of the thermometer bulb. The distance from the bulb of the thermometer to the outlet end of the condenser tube shall be not more than 24 nor less than 20 in. The burner should be protected from draughts by a suitable shield or chimney (see Fig. 7).

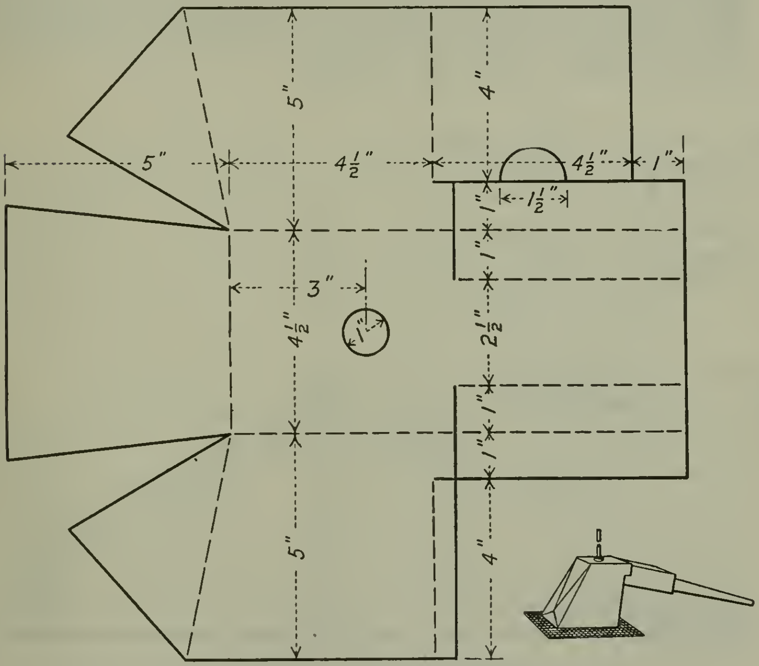

FIG. 7.—Asbestos Shield.

Distillation Test. 11. Exactly 100 g. of oil shall be weighed into the retort, the apparatus assembled and heat applied. The distillation shall be conducted at the rate of at least one drop and not more than two drops per second, and the distillate collected in weighed receivers. The condenser tube shall be warmed whenever necessary to prevent accumulation of solid distillates. Fractions shall be collected at the following points: 210, 235, 270, 315 and 355° C. The receivers shall be changed as the mercury passes the dividing temperature for each fraction. When the temperature reaches 355°, the flame shall be removed from the retort, and any oil which has condensed in the offtake shall be drained in the 355° fraction.

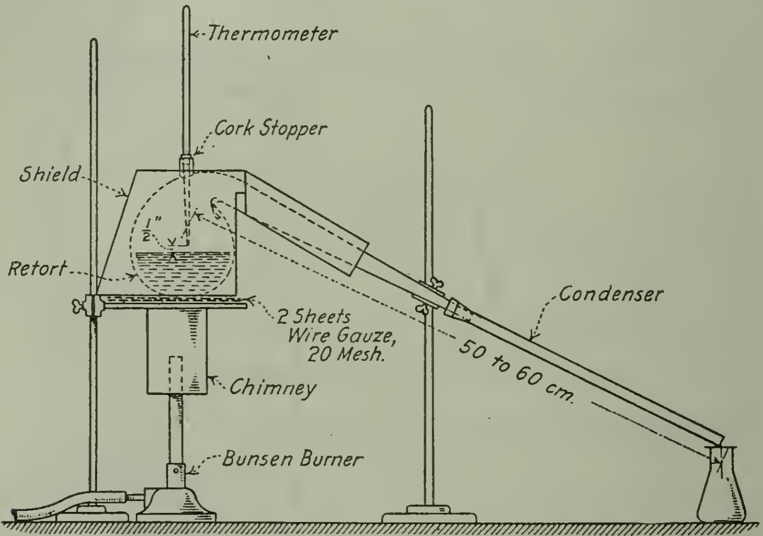

FIG. 8.—Assembled Apparatus for Distillation Test.

The residue shall remain in the retort with the cork and the thermometer in position until no vapors are visible; it shall then be weighed. If the residue is to be further tested it shall then be poured directly into the brass collar used in the float test[1] or into a tin box and covered and allowed to cool to air temperature. If the residue becomes so cool that it cannot be poured readily from the retort, it shall be re-heated by holding the bulb of the retort in hot water or steam, and not by the application of flame.

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[1] See "Float Test of Residue," p. 816.

For weighing the receivers and fractions, a balance accurate to at least 0.05 g. shall be used.

During the progress of the distillation the thermometer shall remain in its original position. No correction shall be made for the emergent stem of the thermometer.

When any measurable amount of water is present in the distillate it shall be separated as nearly as possible and reported separately, all results being calculated on a basis of dry oil. When more than 2 per cent of water is present, water-free oil shall be obtained by separately distilling a larger quantity of oil, returning to the oil any oil carried over with the water, and using dried oil for the final distillation. (See "Water Test.")

SPECIFIC GRAVITY OF FRACTIONS.

Specific Gravity of Fractions.

12. As specific gravity is an absolute physical determination, any recognized method which can be applied to the quantity and quality of material at hand to be tested must be considered satisfactory. The following methods are convenient and accurate means for the relatively small amounts of oil available in determining specific gravity of fractions to be tested.

(a) Liquid Fractions.

Apparatus.

13. The Westphal balance may be used.

Test.

14. If the fraction to be tested is liquid at a temperature not exceeding 60° C., the Westphal balance can be used with convenience and rapidity. A special type of Westphal balance is obtainable, designed for testing very small quantities. However, the ordinary type of Westphal balance can be adapted to testing small fractions by the use of a special plummet. When using the ordinary balance with the special plummet, extra care is needed that the adjustment of the balance be accurately made. The plummet can readily be made in the laboratory from a piece of ordinary glass tubing 7 mm. outside diameter, sealed at the end, and melting into the glass where sealed a short platinum wire. After cooling place 9 to 10 g. of mercury in the tube, making a column 35 to 40 mm. high. Seal off the tube within 20 mm. of the top of the mercury column with blowpipe flame. The plummet shall have a length of about 55 to 60 mm. over all, and shall weigh between 10 and 12 g.

(b) Solid and Seni-solid Fractions.

Apparatus.

15. A pan of the form shown in Fig. 9, having the following approximate dimensions, may be used:

Diameter of base	20 mm.
Diameter of top	25 "
Depth	12 "
Diameter of wire	1 "
Total weight	7 g.

The pan and wires are made of platinum or nickel.

Test. 16. Solid or semi-solid fractions of oil which cannot be readily liquefied can be rapidly and accurately tested in this apparatus by the usual method of weighing in air and in water. The usual precautions of igniting the pan before use, and avoiding the enclosure of air or water in the sample, should be observed.

NOTE.—The method for liquid fractions is usually applicable to the fractions 235 to 315° C. and the method for solid and semi-solid fractions to the fraction 315 to 355° C.

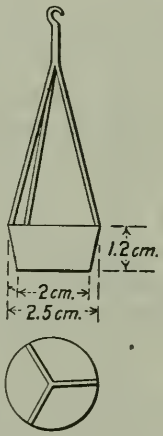


FIG. 9.—Platinum or Nickel Pan.

FLOAT TEST OF RESIDUE.

Apparatus. 17. (*a*) *Float or Saucer.*—The float or saucer shall be made of aluminum, and shall be of the form and dimensions shown in Fig. 10.

(*b*) *Conical Collar.*—The conical collar shall be made of brass, and shall be of the form and dimensions shown in Fig. 11.

Float Test Residue. 18. Place the brass collar with the small end on the brass plate, which has been previously amalgamated with mercury by first rubbing it with dilute solution of mercuric chloride or nitrate and then with mercury. Pour the residue to be tested into the collar direct from the retort, as described under "Distillation," or heat it in a tin box on water or steam bath, not by direct application of flame, and then pour into the collar in any convenient way, until slightly more than level with the top. The surplus may be removed after the material has cooled to room temperature, by means of spatula or steel knife which has been slightly heated. Then place the collar and plate in one of the tin cups containing ice water maintained at 5° C., and leave in this bath for at least 15 minutes.

Meanwhile, fill the other cup about three-fourths full of water and place on the tripod; heat the water to any desired temperature at which the test is to be made. This temperature should be accurately maintained, and should at no time throughout the entire test be allowed to vary more than 0°.5 C. from the temperature specified.

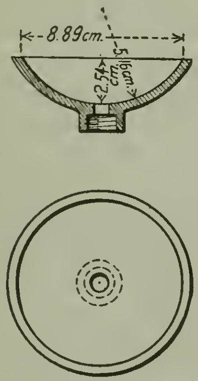


FIG. 10.—Float or Saucer.

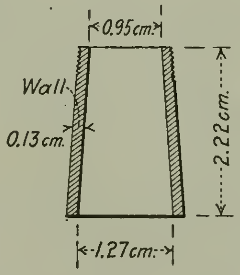


FIG. 11.—Conical Collar.

After the material to be tested has been kept in the ice water for at least 15 minutes and not more than 30 minutes, remove the collar with its contents from the plate and screw into the aluminum float, which is then immediately floated in the warmed bath. As the plug of residue becomes warm and fluid, it is forced upward and out of the collar, until the water gains entrance to the saucer and causes it to sink.

The time in seconds between placing the apparatus on the water and when the water breaks through the residue shall be determined by means of a stop watch, and shall be taken as a measure of the consistency of the material under examination.

COKE RESIDUE.

Apparatus.

19. *Bulb.*—The bulb shall be of hard glass, as shown in Fig. 12, and shall have the following approximate dimensions:

Diameter of bulb	15 mm.
Length of vertical neck	10 "
Length of horizontal neck	20 "
Diameter of orifice	1 "

Coke Residue Test.

20. Warm the bulb slightly to drive off all moisture, cool in a desiccator, and weigh. Again heat the bulb by placing it momentarily in an open Bunsen flame and place the tubular underneath the surface of the oil to be tested and allow the bulb to cool until sufficient oil is sucked in to fill the bulb about two-thirds full.

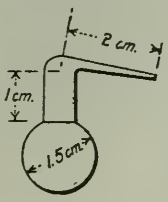


FIG. 12.—Coke Bulb.

Any globules of oil sticking to the inside of the tubular should be drawn into the bulb by shaking or expelled by slightly heating it, and the outer surface should be carefully wiped off and the bulb reweighed. This procedure will give about 1 g. of oil.

Cut a strip of thin asbestos paper about $\frac{1}{4}$ in. wide and about 1 in. long, place it around the neck of the bulb and catch the two free ends close up to the neck with a pair of crucible tongs. The oil should then be distilled off as in making ordinary oil distillation, starting with a very low flame and conducting the distillation as fast as can be maintained without spurting.

When oil ceases to come over, the heat should be increased until the highest temperature of the Bunsen flame is attained, the whole bulb being heated red hot until evolution of gas ceases, and any carbon sticking to the outside of the tubular is completely burned off. The bulb should then be cooled in a desiccator and weighed and the percentage of coke residue calculated to water-free oil.

STANDARD DEFINITIONS
OF
TERMS RELATING TO STRUCTURAL TIMBER.

Serial Designation: D 9 – 15.

These definitions are issued under the fixed designation D 9; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1907; Revised, 1915.

I. DEFINITION OF STRUCTURAL TIMBER.

By the term "Structural Timber" is understood all such products of wood in which the strength of the timber is the controlling element in their selection and use. The following is a list of products which are recommended for consideration as structural timbers:

Trestle Timbers.—Stringers, caps, posts, mud sills, bracing, bridge ties, guard rails.

Car Timbers.—Car framing, including upper framing; car sills.

Framing for Buildings.—Posts, mud sills, girders, framing joists.

Ship Timbers.—Ship timbers, ship decking.

Cross Arms for Poles.

II. STANDARD DEFECTS.

Measurements which refer to the diameter of knots or holes should be considered as referring to the mean or average diameter.

1. *Sound Knot.*—A sound knot is one which is solid across its face and which is as hard as the wood surrounding it; it may be either red or black, and is so fixed by growth or position that it will retain its place in the piece.

2. *Loose Knot.*—A loose knot is one not firmly held in place by growth or position.

3. *Pith Knot.*—A pith knot is a sound knot with a pith hole not more than $\frac{1}{4}$ in. in diameter in the center.

4. *Encased Knot.*—An encased knot is one whose growth rings are not intergrown and homogeneous with the growth

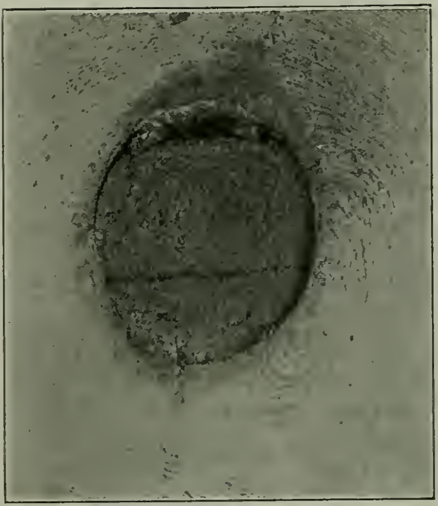


FIG. 1.—Loose Knot.

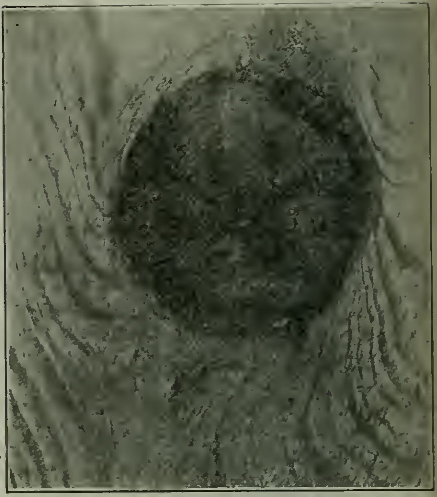


FIG. 3.—Encased Knot.

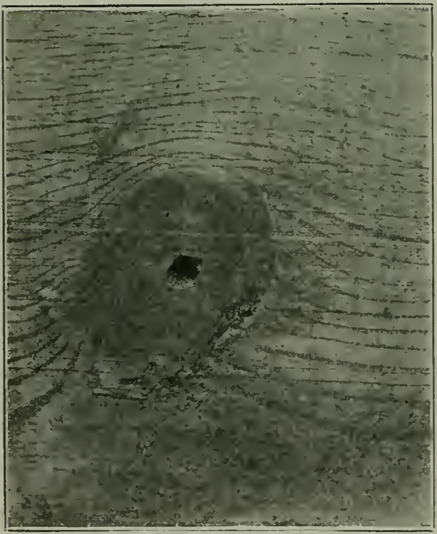


FIG. 2.—Pith Knot.

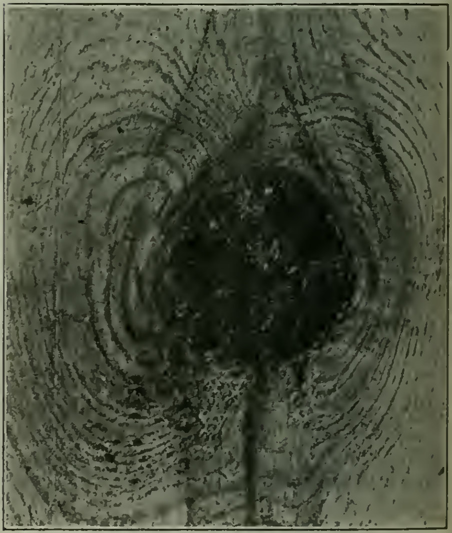


FIG. 4.—Rotten Knot.

rings of the piece it is in. The encasement may be partial or complete; if intergrown partially or so fixed by growth or position that it will retain its place in the piece, it shall be considered a sound knot; if completely intergrown on one face, it is a watertight knot.

5. *Rotten Knot.*—A rotten knot is one not as hard as the wood it is in.

6 *Pin Knot.*—A pin knot is a sound knot not over ½ in. in diameter.

7. *Standard Knot.*—A standard knot is a sound knot not over 1½ in. in diameter.

8. *Large Knot.*—A large knot is a sound knot, more than 1½ in. in diameter.

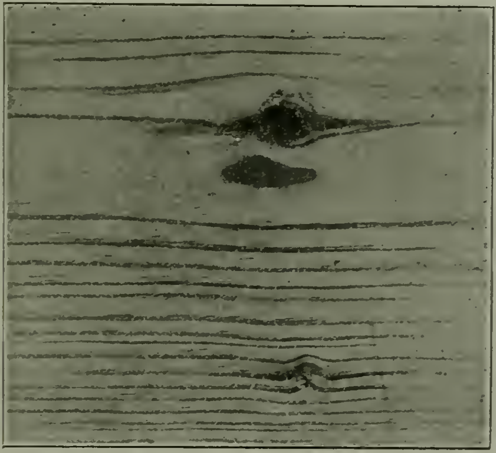


FIG. 5.—Pin Knot.

9. *Round Knot.*—A round knot is one which is oval or circular in form.

10. *Spike Knot.*—A spike knot is one sawn in a lengthwise direction; the mean or average width shall be considered in measuring these knots.

11. *Pitch Pockets.*—Pitch pockets are openings between the grain of the wood containing more or less pitch or bark. These shall be classified as *small*, *standard* and *large* pitch pockets.

(*a*) *Small Pitch Pocket.*—A small pitch pocket is one not over ⅛ in. wide.

(*b*) *Standard Pitch Pocket.*—A standard pitch pocket is one not over ⅜ in. wide, or 3 in. in length.

(*c*) *Large Pitch Pocket.*—A large pitch pocket is one over $\frac{3}{8}$ in. wide, or over 3 in. in length.

12. *Pitch Streak.*—A pitch streak is a well-defined accumulation of pitch at one point in the piece. When not sufficient to develop a well-defined streak, or where the fiber between grains, that is, the coarse-grained fiber, usually termed "spring wood," is not saturated with pitch, it shall not be considered a defect.

13. *Wane.*—Wane is bark, or the lack of wood from any cause, on edges of timbers.

14. *Shakes.*—Shakes are splits or checks in timbers which usually cause a separation of the wood between annual rings.

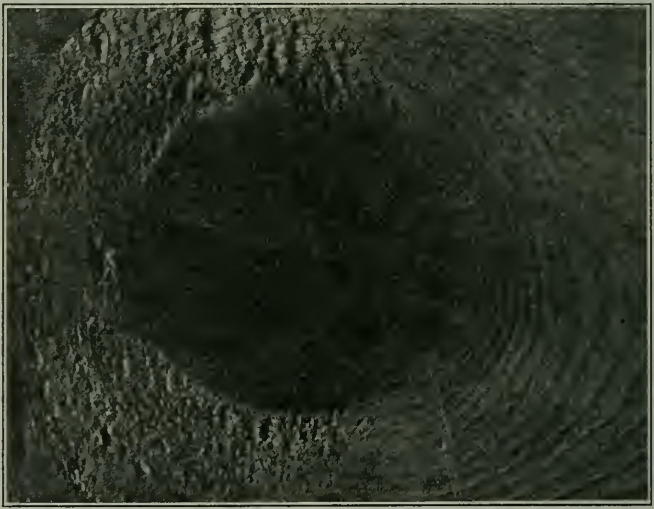


FIG. 6.—Standard Knot.

15. *Rot, Dote and Red Heart.*—Any form of decay which may be evident either as a dark red discoloration not found in the sound wood, or the presence of white or red rotten spots, shall be considered as a defect.

16. *Ring Shake.*—An opening between the annual rings.

17. *Through Shake.*—A shake which extends between two faces of a timber.

III. STANDARD NAMES FOR STRUCTURAL TIMBERS.

1. *Southern Yellow Pine.*—This term includes the species of yellow pine growing in the southern states from Virginia to

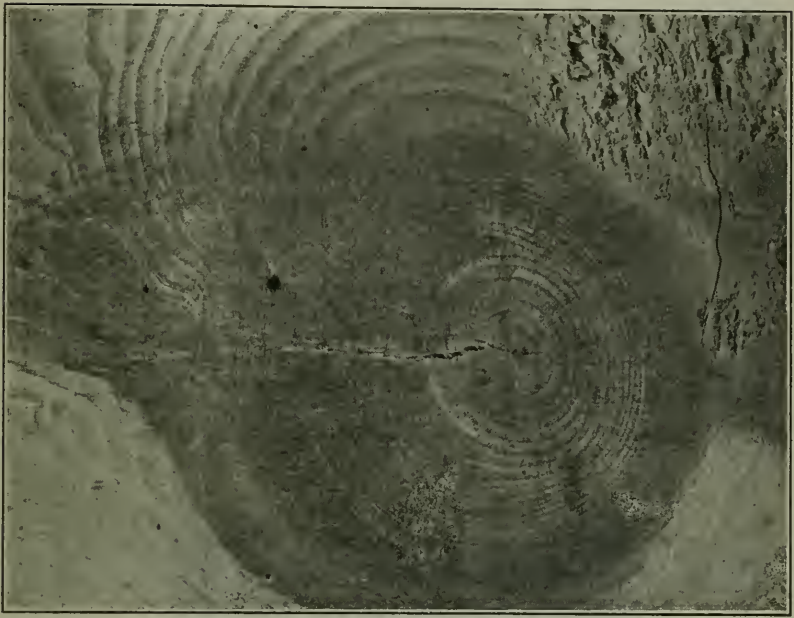


FIG. 7.—Large Knot.

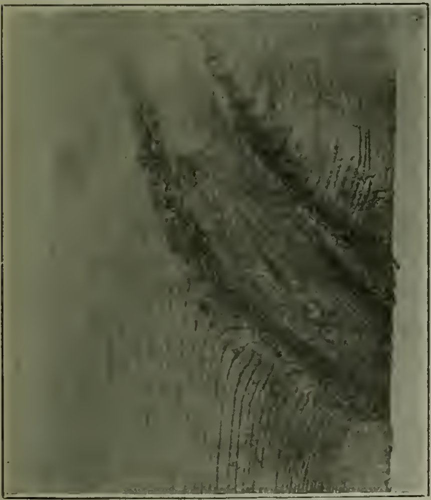


FIG. 8.—Spike Knot.

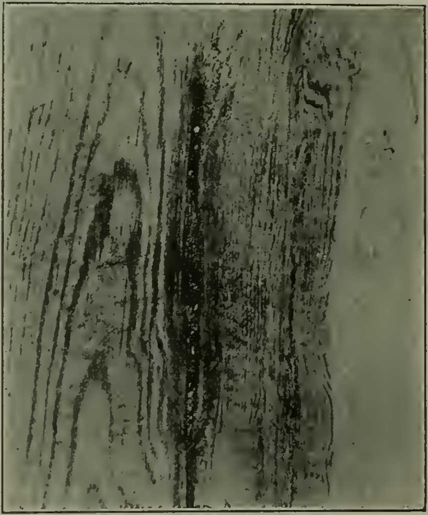


FIG. 9.—Pitch Pocket.

Texas, that is, the pines hitherto known as longleaf pine (*Pinus palustris*), shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), Cuban pine (*Pinus heterophylla*) and pond pine (*Pinus serotina*).

Under this heading, two classes of timber are designated: (*a*) dense southern yellow pine and (*b*) sound southern yellow pine. It is understood that these two terms are descriptive of quality rather than of botanical species.

(*a*) Dense southern yellow pine shall show on either end an average of at least six annual rings per inch and at least one-third summer wood, or else the greater number of the rings shall show at least one-third summer wood, all as measured over the third, fourth, and fifth inches on a radial line from the pith. Wide-ringed material excluded by this rule will be acceptable, provided that the amount of summer wood as above measured shall be at least one-half.

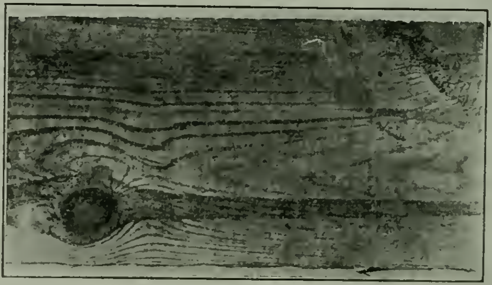


FIG. 10.—Pitch Streak.

The contrast in color between summer wood and spring wood shall be sharp and the summer wood shall be dark in color, except in pieces having considerably above the minimum requirement for summer wood.

(*b*) Sound southern yellow pine shall include pieces of southern pine without any ring or summer-wood requirement.

2. *Douglas Fir.*—The term "Douglas Fir" is to cover the timber known likewise as yellow fir, red fir, western fir, Washington fir, Oregon or Puget Sound fir or pine, norwest and west coast fir.

3. *Norway Pine*, to cover what is known also as "Red Pine."

4. *Hemlock*, to cover Southern or Eastern hemlock; that is, hemlock from all States east of and including Minnesota.

5. *Western Hemlock*, to cover hemlock from the Pacific coast.

6. *Spruce*, to cover Eastern spruce; that is, the spruce timber coming from points east of and including Minnesota.

7. *Western Spruce*, to cover the spruce timber from the Pacific coast.

8. *White Pine*, to cover the timber which has hitherto been known as white pine, from Maine, Michigan, Wisconsin and Minnesota.

9. *Idaho White Pine*, the variety of white pine from western Montana, northern Idaho, and eastern Washington.

10. *Western Pine*, to cover the timber sold as white pine coming from Arizona, California, New Mexico, Colorado, Oregon and Washington. This is the timber sometimes known as "Western Yellow Pine," or "Ponderosa Pine," or "California White Pine," or "Western White Pine."

11. *Western Larch*, to cover the species of larch or tamarack from the Rocky Mountain and Pacific coast regions.

12. *Tamarack*, to cover the timber known as "Tamarack," or "Eastern Tamarack," from States east of and including Minnesota.

13. *Redwood*, to include the California wood usually known by that name.

STANDARD METHODS OF TESTING COTTON RUBBER-LINED HOSE.

Serial Designation: D 15 – 15.

These methods are issued under the fixed designation D 15; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Adopted, 1915.

Methods for the Chemical Analysis of Rubber Lining.

I. SAMPLING.

Samples. 1. Samples shall be taken both as to number and location at the discretion of the inspector.

Blanks. 2. Blank tests shall be run on all determinations and deductions made accordingly.

Checks. 3. In the event of any determination not falling within the limits given in these methods of test, a duplicate determination which shall agree within the limits specified shall be made and the average value taken as the true value.

Preparation of Sample. 4. A sample of not less than 15 g., taking pieces from various parts of the rubber for analysis, shall be prepared. The backing shall be buffed off before grinding.

Grinding. 5. The sample shall be cut into small pieces and run through the grinder until all of it will pass a 20-mesh sieve. Care must be taken that the grinder does not become appreciably warm.

Removal of Iron and Care of Sample. 6. A strong magnet shall be passed through the sample to remove any metal from the grinder, and the sample shall be mixed thoroughly and put in tightly stoppered bottles. It shall not be exposed to sunlight or heat.

II. REAGENTS.

Acetone. 7. Acetone shall be distilled not more than 10 days before use over anhydrous potassium carbonate, using the fraction which distills at 56 to 57° C.

Alcoholic Potash. 8. Alcoholic potash shall be of normal strength, made by dissolving the required amount of potassium hydroxide in absolute alcohol the day before use and allowing to settle. Only the clear solution shall be used.

Barium-Chloride Solution. 9. Barium-chloride solution shall be made by dissolving 100 g. of crystallized barium chloride in one liter of distilled water and adding two or three drops of concentrated hydrochloric acid. If there is any insoluble matter or cloudiness the solution shall be heated on the steam bath over night and filtered.

All reagents shall be of a purity equal to that called for in Krauch's "Standard Chemical Reagents; their Purity and Test."

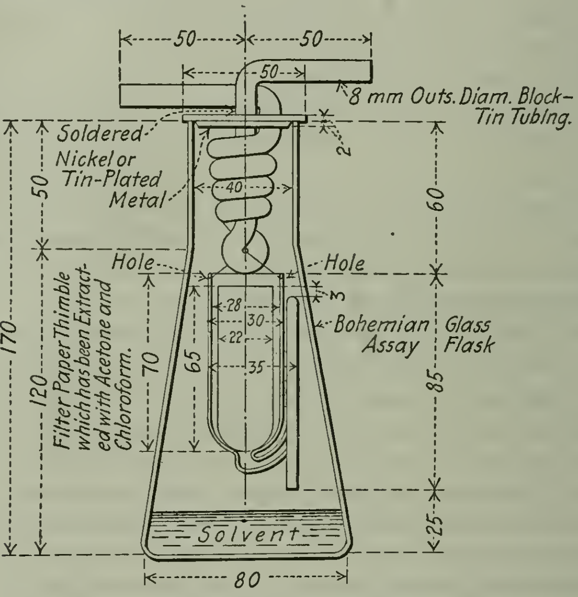
III. ANALYSES.

Acetone Extract. 10. The extraction apparatus shall conform to that shown in Fig. 1. It shall be heated so that the period of filling an empty syphon cup with acetone and completely emptying it will be between 2½ and 3½ minutes.

Two grams of the rubber shall be extracted continuously with acetone for 8 hours, using a sample that has been prepared within 24 hours. Distill off the acetone and dry the flask and contents for 4 hours at 95 to 100° C. Desiccate until cool and weigh. Continue to dry for 2-hour periods until constant weight is obtained. In drying, place the flask on its side but at a sufficient angle from the horizontal so that the extract does not appreciably run down from the side of the flask.

Free Sulfur. 11. Add to the flask containing the acetone extract 50 to 60 cc. of distilled water and 2 or 3 cc. of bromine (if the acetone extract indicates a large amount of free sulfur the amount of bromine should be increased). Heat gently on the steam bath until the solution is practically colorless and filter into a 400-cc. beaker. Dilute with distilled water until the volume is about 400 cc. Cover the beaker with a watch glass, heat to boiling on the steam bath, add 10 cc. of 10-per-cent barium-chloride solution and allow the precipitate to stand over night. The next day filter off the precipitate, ignite the filter paper and weigh.

Alcoholic-Potash Extract. 12. Dry the residue from the acetone extraction at 50 to 60° C., put into a 200-cc. Erlenmeyer flask with 50 cc. of the alcoholic KOH solution and boil for 4 hours under a reflux condenser. Filter the solution into a beaker and wash twice, using each time 25 cc. of hot absolute alcohol and then wash thoroughly with hot water. Evaporate the solution to approximate dryness, take up in warm water and transfer to a separatory funnel. Acidify with 15 cc. 5 normal HCl, using this to rinse the beaker. Add sufficient water to make the bulk of the solution 100 cc. When cool add 40 cc. of ether, using it to rinse the beaker in 20-cc. portions. Shake the aqueous and ethereal solutions thoroughly. After complete separation, draw off the aqueous solution and treat in another separatory funnel, with a fresh 20-cc. portion of ether. Continue to shake the aqueous solution with fresh portions of ether until a colorless portion has been obtained, then shake out twice more. Unite the ethereal solutions and wash with successive additions of water, continuing twice after the water shows no acid reaction. Filter through a plug of extracted cotton into a tared flask, wash the filter and funnel with ether, evaporate the ether without boiling and dry the residue to constant weight at 95 to 100° C. Cool in a desiccator and weigh.



50
50
50
8 mm Outs. Diam. Block-Tin Tubing.
Soldered
Nickel or Tin-Plated Metal
2
40
60
Hole
Hole
3
28
30
22
35
Bohemian Assay Glass Flask
170
120
50
70
65
Filter Paper Thimble which has been Extracted with Acetone and Chloroform.
85
25
Solvent
80

(All dimensions in millimeters.)

FIG. 1.—Extraction Apparatus.

Total Sulfur. 13. Mix a 0.5-g. sample with 4 g. of Na_2O_2 and 6 g. of K_2CO_3 in a dry 15-cc. iron crucible. Cover and heat gradually until the mixture fuses, proceeding cautiously, as rapid heating will cause an explosion. Then bring to quiet fusion for 15 to 20 minutes, applying heat so as to avoid contamination with sulfur fumes. Rotate the crucible while the melt solidifies. When cool, put crucible and cover into a casserole containing 200 cc. of water; add 5 to 10 cc. of bromine water and boil until the melt is dissolved. Allow the precipitate to settle, decant the liquid through a thick filter and wash the residue with hot water. Acidify the filtrate with HCl, evaporate to dryness and dehydrate if silica is present; add 2 cc. of concentrated HCl, take up in water, filter and wash, making the total volume about 400 cc. Heat to boiling and add slowly a slight excess of hot 10-per-cent barium-chloride solution. Allow to stand over night, filter, wash, ignite, weigh the $BaSO_4$ and calculate to sulfur.

Ash.

14. Weigh out a 1-g. sample in a porcelain crucible, heat in a muffle furnace, the temperature of which is carefully regulated so that no material amount of visible products are given off. After the mass is charred the temperature shall be raised sufficiently to burn the carbon. The whole process shall be conducted at as low a temperature as possible. At the end of this operation the crucible shall be removed from the furnace, cooled in a desiccator and weighed; the ash broken up and inspected for carbon. If any visible carbon is present a new determination shall be conducted.

IV. CALCULATIONS.

Calculations.

15. The percentage of rubber shall be considered to be the difference between 100 and the sum of the total sulfur and ash expressed as percentages and figured on the total compound. If the alcoholic-potash extract is over 2 per cent of the rubber as first calculated, subtract this excess also from the rubber. The organic-acetone extract shall be obtained by taking the difference between the total acetone extract and the free sulfur. The organic-acetone extract, free sulfur, total sulfur and alcoholic-potash extract shall be figured on the amount of gum as found by the above procedure.

V. CHECK ANALYSES.

Check Analysis.

16. Duplicate determinations when required shall check within the following limits, expressed as percentages of the gum present, as found by analysis, except as stated.

	CHECK WITHIN, PER CENT.
Organic-acetone extract	0.10
Free sulfur	0.10
Total sulfur	0.10
Alcoholic-potash extract	0.10
Ash calculated on total compound	0.25

METHODS FOR THE PHYSICAL TESTING OF RUBBER LINING AND COTTON FABRIC OF RUBBER-LINED HOSE.

VI. SAMPLING OF RUBBER LINING.

Sampling. 17. Samples shall be taken both as regards to number (except where limited by the specifications) and location at the discretion of the inspector. All samples shall be cut transversely from the hose.

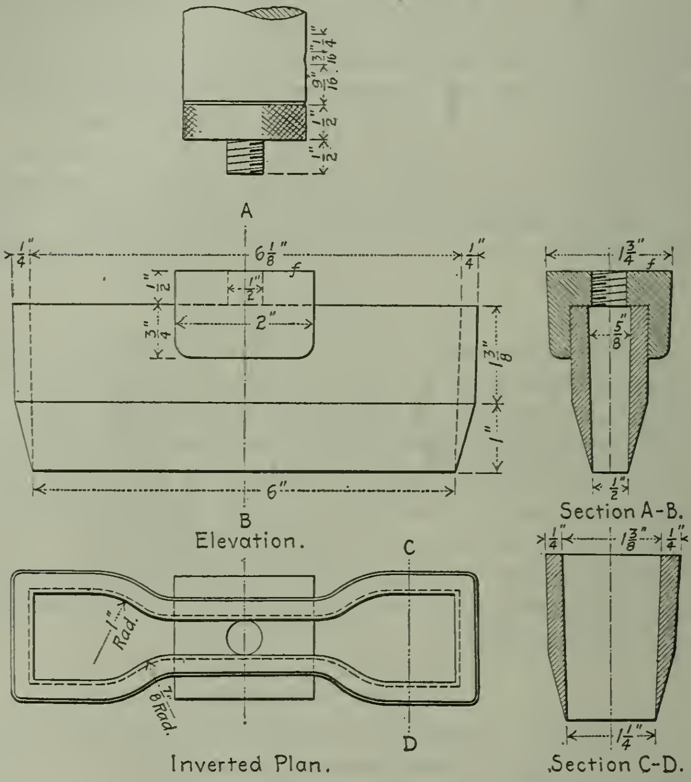


FIG. 2.—Die.

Average. 18. Not less than three pieces from each sample shall be tested and their results taken in calculating the average, unless some individual result is apparently in error in which case a retest shall be made.

Temperature of Testing Room and all Samples. 19. Tests of rubber shall be made with the temperature of the air not lower than 65 or higher than 90° F., and the samples shall be kept at temperatures within these limits, for at least one half hour previous to the time of test.

VII. PREPARATION OF TEST SPECIMENS OF RUBBER LINING.

Preparation of Test Specimens.

20. (*a*) Test specimens of rubber shall be stamped out with a die constructed in accordance with Fig. 2.

(*b*) All specimens for these tests shall have the backing entirely removed by means of a grinder shown in Fig. 3.

Test specimens which have become burnt in buffing shall be discarded.

(*c*) If it is necessary to use naphtha to separate the rubber from the fabric, the naphtha shall be what is technically known as 76° Baumé, free from oil. When naphtha has been used the test specimen shall be allowed to remain at rest for not less than one hour before testing. In all cases after buffing the test specimen shall remain at rest not less than ten minutes before testing.

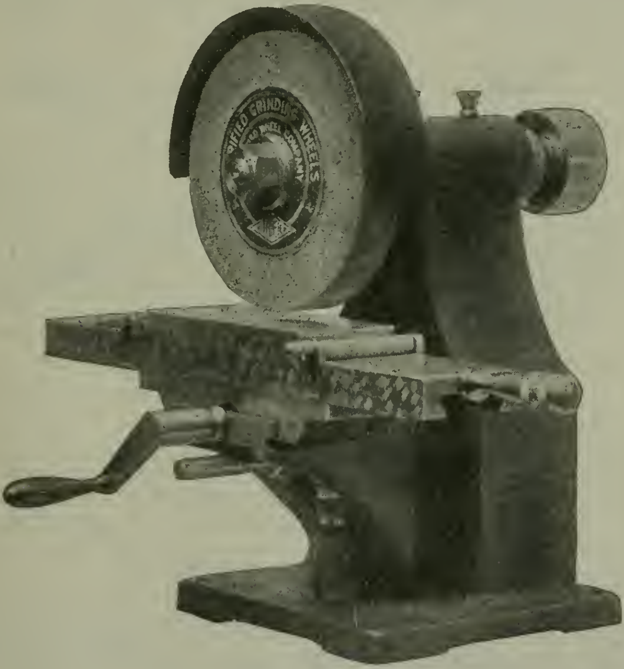


FIG. 3.—Grinder.

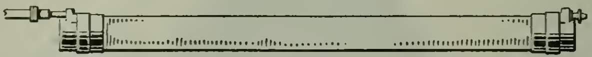
VIII. PHYSICAL TESTS OF RUBBER LINING.

Friction Test.

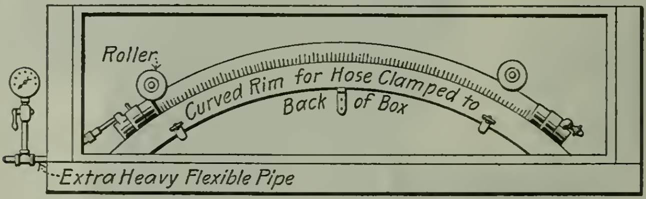
21. Test specimens shall be accurately cut transversely $1\frac{1}{2}$ in. wide and the full length of the circumference. They shall be

cut through the walls so that they can be laid out flat the full length of the piece. One-quarter inch of the rubber lining shall be carefully and cleanly trimmed off on each side without injuring the fabric, leaving a strip of rubber lining 1 in. wide undisturbed on a strip of cover 1½ in. wide. A separation between lining and cover of this strip shall be started for about 1½ in. The free end of fabric shall then be clamped in a fixed jaw so that the hose will hang approximately vertical. The free end of rubber lining shall be clamped to a movable jaw to which is suspended a specified weight, and the rate of separation noted.

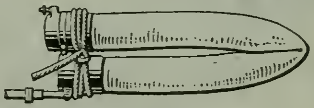
Tensile Strength. 22. Tensile strength tests shall be made on an apparatus,



Test 1. Hose Straight.


Roller
Curved Rim for Hose Clamped to Back of Box
Extra Heavy Flexible Pipe

Test 2. Hose Curved on Radius of 2¼ feet.



Test 3. Hose Kinked, Ends Tied Together.

FIG. 4.—Apparatus for Pressure Test.

the general designs of which conform to the "Schopper" machine. The grips for holding the test specimens shall be such that they will tighten automatically, exerting a uniform pressure across the full width of the piece proportionate to the applied tension. The jaws shall separate at a rate of 20 in. per minute. The thickness of the test specimens shall be accurately determined at three points equidistant between the marks. A spring micrometer gage accurate to within 0.001 in. and having a circular foot 0.4 in. in diameter shall be used.

Elongation at Breaking Point. 23. The elongation at the breaking point shall be determined during the tension test as follows:

Previous to placing in the machine for the tension test, mark with two parallel lines 2 in. apart. For this purpose use a stamp having two marking edges placed 2 in. apart. On the test specimen a rule graduated to at least $\frac{1}{16}$ in. shall be kept opposite the two marks and the distance between the outside edges of these marks noted at the instant of breaking.

Set.

24. The determination of set shall be carried out on a specimen which has not been stretched or used for any other test.

Mark two lines on the test sample 2 in. apart and at right angles to the direction of pull. Place in the tension testing machine, stretch to the amount specified by separating the jaws at the rate of 20 in. per minute and hold in that position 10 minutes; immediately release and 10 minutes thereafter measure the distance between the marks. If the sample breaks prior to being released it shall be considered that it has failed in this test.

Defects.

25. If the break occurs outside the gage marks on the test specimen during the tension test and the tensile strength or stretch are below the requirements, the test shall be repeated.

The broken surfaces of test specimens shall be examined for flaws or defects and if the results of the test confirm the observation of flaws the test shall be repeated.

IX. HYDRAULIC PRESSURE TEST.

Hydraulic Pressure Test of Hose.

26. The determination of bursting or proof pressure shall be made in the following manner:

The hose shall be stretched on a plane surface in a straight line and connected to the water line or pump and filled with water, leaving the air cock open to allow the air to escape. The air cock shall then be closed and a pressure of 10 lb. per sq. in. applied. The test shall then begin by taking original measurements with the pressure at 10 lb. per sq. in. Pressures shall be measured with a standardized gage.

The increase in pressure shall be made at the rate of 300 lb. per minute. The hose while making the elongation and twist measurements shall be held at the specified pressure for not more than two minutes.

In making the bursting test in the curved position the apparatus shown in Fig. 4 shall be used.

The kinked test shall be made on 3-ft. samples with the ends tied together, and the couplings touching with a sharp kink in the middle of the hose; or if made on a 50-ft. sample the hose shall be tied together at a point 18 in. from where the kink occurs.

STANDARD GENERAL METHODS
OF
TESTING COTTON FABRICS.

Serial Designation: D 39 – 20.

These methods are issued under the fixed designation D 39; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1915; Adopted in Amended Form, 1920

1. The following General Methods are intended to be applicable for testing cotton fabrics. Where a material requires special treatment, specific methods will be described as they are developed for that material and such special tests shall have precedence over the general method.

I. CONDITION.

Dry Condition. 2. The dry condition of cotton fabric shall be understood to be absolute dryness obtained by placing material in a ventilated drying oven maintained at a temperature of 105 to 110° C. (221 to 230° F.) and drying to constant weight as determined by two consecutive weighings without removal from the oven, to be taken not less than ten minutes apart, and to show a further loss of not more than 0.1 per cent of the previous weighing.

Standard Condition. 3. The standard condition of cotton fabric shall be understood to be the condition in which it contains 6.5 per cent of its dry weight of moisture.

II. TEST METHODS.

(*A*) *Length.*

Length. 4. The length of a roll or piece shall be determined by running the cloth over a measuring drum of known circumference, from which the yardage is registered by a dial or counter driven by a chain or other positive or non-slip mechanism.

Just enough uniform tension[1] is to be used on the cloth to keep it running flat and true.

(*B*) *Width.*

Width. 5. (*a*) The width of a roll or piece shall be determined at five different places uniformly distributed along the full length of the roll or piece, and may be determined at the same time as the total length.

(*b*) The average of the five measurements shall be the width.

(*C*) *Weight.*

Normal Weight. 6. (*a*) *Preferred Method.*—The net weight of the roll or piece from which covering and binding have been removed shall be determined. The net weight of the roll or piece divided by its superficial area in square yards shall be taken as the normal net weight per square yard.

(*b*) *Alternative Method.*—Three samples of known area, to contain not less than 4 sq. in. each, shall be stamped (preferably cut with a steel die) from one end of the roll or piece and quickly weighed. The normal square yard weight shall be computed from the average weight of these three samples.

Dry Weight. 7. (*a*) *Preferred Method.*—For the determination of dry weight two test specimens of approximately equal area, each not less than 4 in. in length and of the entire width of the fabric, shall be cut one from each end of the roll or piece. The one from the outside end of the roll shall be taken as soon as the wrapping is removed and the one from the inner end of the roll as soon as the inner end of the roll has been reached in running the roll. The two samples shall be taken as soon as possible. These samples shall be placed in a dry air-tight container, the weight of which has been previously determined, and carefully weighed therein and then removed (check weight being made on container), the net weight calculated and the sample dried to constant weight in manner described in Section 2. The difference between the original weight of sample and the dry weight is the loss of moisture which when computed as percentage of the dry weight is the percentage regain of the material. The dry weight per square yard is then obtained from the normal weight per square yard as obtained in Section 6 (*a*), as follows:

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[1] It has been suggested that a uniform tension of 2.5 times the weight of five running yards of the fabric will be sufficient to keep the fabric flat and preserve a proper relation for comparison of different fabrics. Invitation is extended to report the results of such tests upon different fabrics.

$$\frac{\text{Normal weight per sq. yd.} \times 100}{100 + \text{percentage regain}} = \text{Dry weight per square yard.}$$

(*b*) *Alternative Method.*—From one end of the roll or piece five specimens, each 3 by 4.32 in., representing 0.01 sq. yd., shall be stamped (preferably cut with a steel die). Two specimens shall be cut near the selvages, one at the center, and the other two between the selvages and the center. These five specimens, with a total area equal to 0.05 sq. yd., shall be placed in the wire basket of a ventilated drying oven. The basket shall be so constructed with partitions, not less than ¼ in. apart, that the specimens may stand on edge. The specimens shall then be dried to bone dryness as described in Section 2. The combined weight of these specimens after drying represents the dry weight of 0.05 sq. yd. of the fabric, and the dry weight per square yard of the roll or piece is obtained by multiplying the above quantity by 20.

Retest.

8. If by the first tests the fabric fails to meet the specifications a second swatch shall be taken as follows: If the roll or piece is a complete warp, the second swatch shall be cut from the center of the roll or piece. If the roll or piece is a part warp, the second swatch shall be taken not less than 1½ yd. from the other end.

Moisture Content and Regain.

9. The difference between the normal weight of the fabric, Section 6, and the dry weight, Section 7, is the amount of moisture present.

(*a*) When computed as percentage of the normal weight this is the *Moisture Content* of the material.

(*b*) When computed as percentage of the dry weight, this is the *Moisture Regain* of the material.

(*D*) *Number of Threads per Inch.*

Number of Threads per Inch.

10. (*a*) The number of threads per inch or count of the fabric shall be determined by counting a space of not less than 1 in. in at least five different places in the roll or piece.

(*b*) The average of the five determinations shall be the count.[1]

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[1] For tire fabric used for carcass building the number of threads per inch shall be determined by counting a space of 10 in. in at least five different places in the roll or piece, and the average of the five determinations shall be the count.

(*E*) *Thickness.*

Thickness.

11. (*a*) The thickness shall be measured by an automatic micrometer which presses upon at least 0.5 sq. in. of the fabric with a uniform constant pressure, and which is so mounted as to make measurements 6 in. from the selvage.

(*b*) At least ten measurements at different portions of the roll or piece shall be made, and the average shall be the thickness of the fabric.

(*F*) *Strength.*

Tensile Strength.

12. Tensile strength tests shall be made by one of the four methods described as follows in detail, and fabrics shall be tested by the method shown for the classification under which they fall. In each case the results shall be recorded separately for warp and filling.

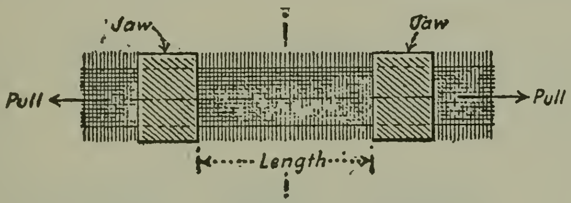


FIG. 1.—Illustration of Strip Test.

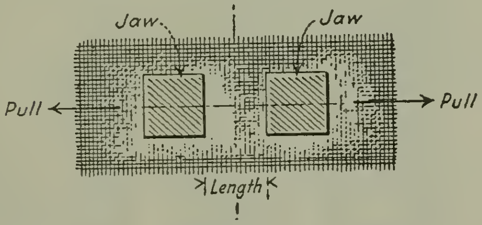


FIG. 2.—Illustration of Grab Test.

For the determination of tensile strength a swatch of the length specified in Table I shall be cut the entire width of the cloth and test specimens shall be cut from this swatch according to the respective diagrams shown at the bottom of Table I.

Two methods of determining the tensile strength shall be recognized:

Strip Test.

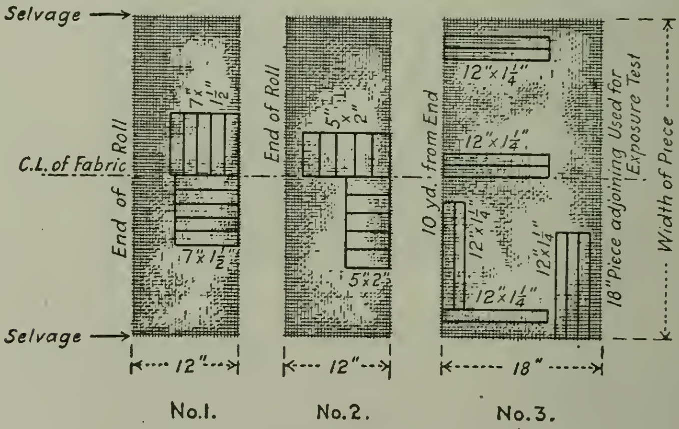
(*a*) *Strip Test* (*Fig. 1*).—Under this method a long narrow strip of the fabric shall be clamped at each end by the jaws of the testing machine and strained to the point of rupture.

Grab Test.

(*b*) *Grab Test* (*Fig. 2*).—Under this method the testing machine jaws, each of definite width, shall be made to reach into the body of a rectangular piece of fabric and shall be clamped a definite distance apart. Care shall be taken that the same set of threads are embraced by both pairs of jaws. The specimen shall then be strained to the point of rupture.

TABLE I.—TENSILE STRENGTH TEST METHODS.

Method No.	1 Strip Method.	2 Grab Method.	3 Strip Method.	4 Single Strand.
Dimensions of specimens, in.	7 by 1½	5 by 2	12 by 1¼	..
Ravelled to standard or specified threads per — in.	1	..	1	..
Min. width of bottom or back jaws, in.	1½	2	1½	..
Width of top or front jaws, in.	1½ (min.)	1	1½ (min.)	..
Distance between jaws, in.	3	1	8	10
Speed of pulling jaw, in. per minute	20	12	12	12
Number of specimens each, warp and filling	5	5	5	20 strand



NOTES.—1. When material is less than 24 in. wide, the swatch shall be cut 24 in. long and the test specimens shall be laid out in such a manner that no part of any specimen shall come within 2 in. of either selvage.

2. When the specified number of threads or picks per inch is in fraction, the number of threads broken shall include the fraction as a full thread.

Correction for Moisture.

13. *Correction for Standard Moisture Regain.*—When it is desired to test specimens for tensile strength in the natural state in which they are cut from the roll or piece, the following method shall be employed to reduce the tensile strength found to the common basis of an assumed Standard Moisture Regain equal to 6.5 per cent of the bone-dry weight:

(*a*) After preparing the specimens for the testing machine, those cut from the warp and those from the filling shall be weighed each in a separate batch under the natural moisture conditions which obtain at the time in the testing room.

(*b*) The specimens shall then be tested immediately, in as rapid succession as possible, by the method specified in Table II.

(*c*) After rupture the broken specimens (entire) shall be placed in the basket of an oven and dried as defined in Section 2.

TABLE II.—TENSILE STRENGTH: TEST METHOD CLASSIFICATION.

Name of Fabric.	Test Method No.	Humidity Conditions.
TIRE FABRICS, including		
Carcass building fabric......	1	Test specimens shall be tested in a dry condition as defined in Section 2. They shall be taken one at a time from the drying oven and broken in the testing machine within 30 seconds from the time of removal from the oven.
Chafing strip..............	1	
Breaker strip..............	1	
Cord fabric................	4	
DUCKS, including		
Hose duck..................	2	(*a*) Specimens may be broken in dry condition as specified above for tire fabrics, such tests to be captioned, "Tested Bone Dry." (*b*) Specimens may be tested in their natural condition as taken from the roll or piece and corrected for the moisture present by the method of Section 12, such tests to be captioned. "Corrected for Standard Moisture Regain."
Belt duck..................	2	
Tent duck..................	2	
Army duck..................	2	
Enamelling duck............	2	
Sail duck..................	2	
Numbered duck..............	2	
DRILLS.....................	2	
SHEETINGS..................	2	
OSNABURG...................	2	
COUTILS....................	2	
BALLOON CLOTH[1]............	1	
WING FABRIC[2]..............	3	Exposed before testing for at least two hours in an atmosphere of 65 per cent relative humidity and 70° F. and tested in this atmosphere.

[1] Balloon cloth shall be tested on machine of the inclination balance type with maximum capacity of 400 lb.

[2] The elongation of wing fabric shall be observed for each specimen when subjected to loads of 10 lb., 20 lb., and 70 lb. Wherever possible autographic records shall be taken.

NOTE.—Fabrics not included in the above list will be given a test method classification by Committee D-13 on application of those interested.

(*d*) The total warp and filling specimens shall be grouped each by themselves, forming two batches. The aggregate dry weight of the warp and filling specimens shall thus be obtained and the Moisture Regain at the time of the test determined.

(*e*) The following formula shall then be applied, based upon the assumption that the Standard Moisture Regain of manufactured cotton is 6.5 per cent of the dry weight, that the

Actual Percentage Regain is between the limits of 3 and 6.5 per cent of the dry weight, and that for 1 per cent of moisture regain there is an increase of 6 per cent in the tensile strength of the fabric.

$$\begin{array}{l}\text{Tensile Strength corrected}\\ \text{to Standard Moisture Regain}\end{array} = \frac{(\text{Tensile Strength from machine reading}) \times 139}{100 + (6 \times \text{Actual Percentage Regain})}$$

Example.—A specimen of fabric broken under natural conditions gave a tensile strength of 294 lb. as read from the machine dial. By weighing before and after drying the specimen was found to contain a Moisture Regain equal to 3 per cent of the bone-dry weight. The tensile strength corrected to a common basis of 6.5 per cent Moisture Regain would therefore be

$$\text{Tensile Strength corrected} = \frac{294 \times 139}{100 + (6 \times 3)} = 346 \text{ lb.}$$

STANDARD METHODS OF MECHANICAL TESTING
OF
METALLIC MATERIALS.

Serial Designation: E 1–18.

These methods are issued under the fixed designation E 1; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

I. Adopted, 1910; Revised, 1916, 1918.
II. Adopted, 1910; Revised, 1916.
III. Adopted, 1911.
IV. Adopted, 1915.

I. METHODS FOR TENSION TESTS.

1. *Definition of Terms.*

Elastic Limit is the greatest load per unit of original cross-section which does not produce a permanent set.

This determination is rarely made in the commercial testing of materials.

Proportional Limit is the load per unit of original cross-section at which the deformations cease to be directly proportional to the loads.

This determination is rarely made in the commercial testing of materials.

Yield Point is the load per unit of original cross-section at which a marked increase in the deformation of the specimen occurs without increase of load. It is usually determined by the drop of the beam of the testing machine, or by the use of dividers.

2. Information obtained from the various laboratories in which tension tests are made shows that in many cases the forms and dimensions of specimens as recommended by the American Society for Testing Materials are in use, and that in other cases these forms and dimensions most nearly reconcile the differences that exist between the various forms employed.

3. It is therefore recommended that the selection of specimens, and their forms and dimensions, shall conform to the specifications for each material, as are now adopted by the American Society for Testing Materials.

In the case of flats $\frac{1}{4}$ in. or under in thickness, the dimensions shall be as follows: Width equal to 5 times the thickness of the specimen, except that in no case shall the width be less than $\frac{3}{4}$ in.; gage length equal to 24 times the thickness of the specimen, except that in no case shall the gage length be less than 2 in.

4. It is believed that the distance between the end of gage length and beginning of shoulders, as prescribed in the standard specifications of the American Society for Testing Materials, is ample to avoid interference with proper elongation, and no grounds are found for recommending any change.

5. The pulling speed has a marked influence on the tensile properties shown by materials tested, an increase in speed increasing the values found for yield point and tensile strength. In testing steel and wrought iron in gage lengths of 2 and 8 in. in accordance with the specifications of the American Society for Testing Materials, the speed of the machine, by which is meant the speed of the cross-head when the machine is running idle, shall conform to the following requirements:

The crosshead speed of the testing machine shall be such that the beam of the machine can be kept balanced, but in no case shall the values given in the following table be exceeded:

Specified Minimum Tensile Strength of Material, lb. per sq. in.	Gage Length, in.	Maximum Crosshead Speed, in. per minute, in Determining	
		Yield Point.	Tensile Strength.
80 000 or under	2 8	0.50 2.00	2.0 6.0
Over 80 000	2 8	0.25 0.50	1.0 2.0

6. In determining the elastic limit (so-called) by the method prescribed in the American Society for Testing Materials Specifications for forgings and cold-rolled axles (Serial Designations: A 18, A 19, A 63 and A 22), the crosshead speed for the 2-in. gage length shall not exceed 0.125 in. per minute.

7. In determining the proportional limit, the crosshead speed shall not exceed 0.025 in. per inch of gage length per minute.

8. In determining the modulus of elasticity, the elastic limit, and the proportional limit, the extensometer should be attached to at least two sides of the specimen, to compensate for unequal elongation, for improper holding, or for any slight bending that may exist in the specimen.

9. All authorities seem to regard it as desirable to measure the elongation on two or more sides of the test specimen, and most extensometers provide for so doing.

10. The greatest accuracy is required in determining the modulus of elasticity, since small errors in measuring elongation are of considerable consequence in the result.

11. Since the modulus is determined for points well within the elastic limit, the total elongation to be measured is much smaller than at the elastic limit.

12. The elastic limit should be determined with great care, but any inaccuracy will cause less proportionate error than in the case of the modulus. The yield point, being less well defined, cannot be so closely determined, and it is believed that in most cases the use of dividers instead of an extensometer will give sufficiently accurate results.

13. It is considered undesirable in accurate determinations of the modulus of elasticity to use a shorter gage length than 8 in. It is evident that the greater the total elongation measured, the less will be the error due to inaccuracy of the reading, and the accuracy thus appears to increase directly as the gage length.

14. That the difference between short and long gage lengths has a greater influence in affecting results than other factors (personal error, inaccuracy of the testing machine, etc.), is shown by the closely agreeing readings obtained with the greater lengths.

15. The effect of improper methods of holding specimens could not be established from the results of actual tests. The result of improper methods of gripping materials of low elongation, such as cast iron, is well known, and it is probable that in material of a more ductile nature, the effect is largely local and does not extend to the portion of the specimen within the gage marks.

CONDITIONS TO ENSURE CORRECT TESTING MACHINES.

16. It is recommended that in machines on which specimen tests are made, whether the power be applied hydraulically or by means of screws and gears, the load be measured by a separate system of levers and knife edges, or by a method similar to that employed in the Emery testing machines.

17. All knife edges shall be kept sharp, and free from oil and dirt, and the machine shall be sensitive to a variation in load of one two-hundred-and-fiftieth of the load carried. Design and

workmanship on testing machines shall be good, and they shall be calibrated at least once every six months by the following method:

CALIBRATION OF TESTING MACHINES.

18. Test for accuracy by loading the weighing table with standard weights, and compare the actual weight at each addition with the reading of the beam. If the table is uniformly loaded in this manner with the full amount of weights that it will accommodate, the proportionality of the levers and the weighing beam can be successfully established. This relation, in a properly designed machine, will remain constant for all loads, but as a further test for sensitiveness under greater loads than can be accommodated in this manner, the following procedure is recommended:

19. Place in the machine a tension bar of such cross-section that the maximum capacity will not stress it to the elastic limit. Stress this bar to various extents through the full range of the machine, and at each load balance the beam and place upon the weighing table standard weights of 100 lb. A weight one two-hundred-and-fiftieth of the total load on the machine should produce a readable movement of the beam.

20. Where evidence of the accuracy of the machine over its whole range is desired, a known load may be applied by means of an extensometer and calibrated bar, whose modulus of elasticity has been determined with exactness.

21. It is recommended that a device be adopted conforming to the following requirements, in which the extensometer and bar are permanently attached to each other:

(*a*) The bar shall be of high-elastic-limit material, and of such cross-section that this limit will be well above the total capacity of the machine on which it is to be used.

(*b*) This bar shall be annealed or otherwise treated so as to eliminate internal or unequal stress in the material, and to ensure its elastic modulus being uniform for successive tests.

(*c*) The extensometer shall be permanently attached to the bar, and shall measure the elongation on two opposite sides.

(*d*) The extensometer shall be preferably of the indicating or direct-reading type, and shall indicate to ten-thousandths of an inch or less.

(*e*) The method of securing the bar in the drawheads of the machine shall be positive and without slip, and shall ensure its axial location.

(*f*) The length of the bar measured by the extensometer shall be sufficient that the smallest extensometer division, that is, 0.0001 in., shall correspond to a difference in loading of 0.2 per cent of the capacity of the machine, or less.

(*g*) The extensometer shall be protected from injury by a permanently attached case with cover removable for reading the scale.

(*h*) The apparatus shall be plainly marked with the maximum load that can be safely applied without injury.

(*i*) The apparatus shall itself be calibrated either by the United States Bureau of Standards, or in a manner that will ensure equally trustworthy results.

METHODS OF GRIPPING TEST SPECIMENS.

22. It is recommended that for specimens of rolled material, serrated grips, flat and V-shaped, be adopted, the former for rectangular and the latter for round specimens. Serrated grips with curved faces appear to have no advantage, and to cause crushing of the material.

23. Wedges with ball and socket do not seem to be necessary, and for commercial testing their use has been generally discontinued.

24. Specimens of turned form, with threaded ends, should be secured in such a manner that side bending stresses are avoided.

25. It is considered important for correct results that the specimen be located in the exact center of the heads, and to better secure this condition, the openings in the heads should be lined up with each other by means of a plumb-bob and be tested for parallelism with a spirit level. Each pair of packing pieces and wedges that are to be used together in the same head should correspond exactly in thickness and other dimensions, and the wedges should be inserted an equal distance when the specimen is in place.

SELECTION AND PREPARATION OF SPECIMEN.

26. Specimens representative of steel castings may be cut from the bottom of a sink head or riser, or from a coupon

attached to the casting. In either case the part from which the specimen is taken should be relatively large in proportion to the size of the casting and should be annealed with it.

27. Workmanship on specimens shall be of the most careful nature, and surfaces should be free from nicks and tool marks. All wire edges should be removed and corners generously rounded.

28. If specimens of rolled material are sheared in the rough from sections, at least $\frac{1}{8}$ in. of the material should be removed from the sheared edges in machining.

GENERAL REQUIREMENTS FOR THE MEASURING OF ELONGATION.

29. In determining the modulus of elasticity and the elastic limit, it is recommended that when practicable the elongation be measured in a length not less than 8 in., and that the following requirements be provided for:

(*a*) The specimen shall be round in section, finished as smooth as possible, and shall be provided with threaded ends for attachment to the draw-heads of the machine.

(*b*) The specimen shall be placed in the exact center of the heads, and be secured in some positive manner, so that slip and side bending stresses do not occur.

(*c*) The extensometer should be of a type to measure the elongation on two or more sides of the specimen.

(*d*) It should read to 0.0001 in. or less.

(*e*) It should be of such a design that no change of zero will occur upon release of the load in determining the real elastic limit.

(*f*) The load shall be applied so slowly that simultaneous readings of elongation and load can be obtained with certainty.

(*g*) The testing machine shall have previously been calibrated for accuracy and sensitiveness, and heads lined up and made parallel.

II. METHODS FOR COMPRESSION TESTS.

1. *Definition of Terms.*

Elastic Limit is the greatest load per unit of original cross-section which does not produce a permanent set.

This determination is rarely made in the commercial testing of materials.

Proportional Limit is the load per unit of original cross-section at which the deformations cease to be directly proportional to the loads.

This determination is rarely made in the commercial testing of materials.

Yield Point is the load per unit of original cross-section at which a marked increase in the deformation of the specimen occurs without increase of load. It is usually determined by the drop of the beam of the testing machine, or by the use of dividers.

2. The test specimen shall be a cylinder having plane ends truly normal to its axis.

Only two replies from testing laboratories mention cubes. A cylindrical specimen will usually be cheaper to prepare than a cube. The stresses are probably less uniformly distributed over a square than over a circular section, owing to the influence of the corners, this being especially the case with the internal shearing stresses which accompany the compression.

3. The diameter of the specimen shall be not less than 1 in. nor greater than 1.13 in. A specimen 1 in. in diameter is to be preferred.

The range of diameter mentioned in the replies from testing laboratories is from 1 in. to 1.129 in. A diameter of 1.1284 in. gives a section area of 1 sq. in.

4. The length of the specimen should be between 2.5 and 4 diameters.

Two testing laboratories use a length of 1 diameter, one a length of from 1.5 to 2 diameters, one a length of 2.6 diameters, and one a length of 10.5 diameters. It is believed that a length less than 2.5 diameters is not sufficient for the internal shear to be properly developed, and that such short lengths give a fictitious strength owing to the friction of the bearing plates of the machine, which causes the specimen to assume a barrel-like form.

5. No bedding should be used for the ends of the specimen.

Only one reply favors bedding. It is known by general experience that bedding modifies the breaking load and that different kinds of bedding have different influences.

6. The bearing blocks which transmit the pressure from the testing machine should be truly normal to the plane ends of the specimen. To secure this, one of the blocks should be provided with a hemispherical bearing which can turn freely.

These requirements seem essential in order that the load may not be eccentrically applied to the specimen, and are generally recommended in the replies from testing laboratories.

7. The speed of compression should be slow, not exceeding 0.1 in. per minute. Near the elastic limit and yield point, the load should be increased very slowly.

A lower speed than that stated might be advisable if permitted by the testing machine. Evidently a higher speed may be allowed with a long specimen than with a short one.

8. For determining modulus of elasticity, the linear compression of the specimen should be observed by a precise compressometer which is attached to the specimen and does not touch the bearing blocks of the machine. Readings of the compressometer should be taken for three loads, the first at about one-fourth, the second at about one-half, and the third at about three-fourths of the elastic limit.

It is believed that these measurements are sufficient for most commercial work. Nothing is said about the release of the specimen from load, since opinions differ as to its advisability.

9. To determine the elastic and also the proportional limit, several readings of the compressometer should be taken as that limit is approached for load increments of 1000 lb. per sq. in.

This requirement seems sufficient to determine the proportional limit for materials in which such a limit exists. It does not seem wise to require the first permanent set to be observed for ordinary commercial work.

10. The yield point is to be noted as corresponding to that load for which the compressometer shows a linear compression without an increase in load. In the absence of a compressometer this point may be noted, for ductile materials, by the drop of the scale beam.

This requirement corresponds to the usual practice of testing laboratories. It is regarded as important that the term "elastic limit" should not be used to designate the yield point.

11. Measurements for the modulus of elasticity, elastic limit, proportional limit, and yield point may be made, if desired, on a specimen ranging in length from 10 to 15 diameters.

This clause is inserted because it may often be difficult to apply a compressometer in a length shorter than 4 in.

12. The record of the test should mention any phenomena observed near the elastic limit, proportional limit, and yield point. The manner of final failure should also be noted when the test is carried to this limit.

This requirement furnishes data for comparing the behavior of brittle and ductile metals near critical points of molecular change.

III. METHODS FOR TRANSVERSE TESTS.

1. In the case of cast metals, when transverse tests are to be used to aid in determining the quality of the material, the specimen used shall be cast vertical, shall be $1\frac{1}{4}$ in. in diameter, and long enough to use a span of at least 15 times the diameter.

It is important that a definite and uniform standard be adopted so that the results may be comparable with each other; hence the diameter specified above (sectional area corresponding to practically one square inch). The determination of span is at present the subject of international tests to decide upon a definite distance to replace the present standard of 12 in. It will probably be 16 to 18 in.

The circular section will best secure a uniform thickness of skin, and thus avoid this irregularity when other sections are employed.

In the case of ductile materials (except in impact tests) transverse tests shall never be used to determine the quality of the material, tension tests being those suitable for the purpose.

In small round or square bars of ductile material, both the modulus of rupture and the transverse elastic limit vary considerably with the span.

In the case of tests made for determining constants to be used for designing, the specimen shall conform as nearly as possible with the form and size of the piece to be used. Thus, if I or T-sections are to be used, the specimens shall be of I or T-section. In the case of flat springs or plate glass, they shall be flat; in the case of timber, rectangular; etc.

It is well known that the modulus of rupture varies with the shape of the section, being very much greater in the case of round than in I-sections. Hence the modulus of rupture suitable for use for one would be entirely unsuitable for the other.

In rolled sections, the smaller ones are subjected to a more thorough working in the process of rolling than the larger.

2. In the case of the "Arbitration Bar" adopted for cast iron, the span has been fixed at 12 in., but may be extended as above stated. The bar will serve for cast and brittle materials.

In the case of ductile materials, when the modulus of rupture is desired, the span shall generally be less than 12 or 15 times the depth. Exceptions, however, occur, as in flat springs and in some cases in full-size pieces, when the spans and methods of supporting the ends, etc., shall conform to the conditions of service.

3. In the case of cast and brittle metals, the speed of testing shall not exceed 0.2 in. per minute. For other specimens the speed shall be correspondingly low.

4. The preparation of the specimen shall be such that it truly represents the material itself. The introduction of extraneous influences should be avoided as far as the knowledge of the material will permit. Thus, in cast metals no coupons shall be used; cast materials for tests shall go into dry molds standing vertical.

No specimen shall be machined before testing, except when information is specifically desired regarding the strength of such machined specimens.

5. The transverse yield point for ductile materials shall be noted approximately by the drop of the scale beam.

6. If the transverse elastic limit is to be determined for comparison with that obtained in the tensile test, the successive increments of load in the neighborhood of the transverse elastic limit shall be comparatively small, and after each load has been applied and the corresponding deflection measured by means of the deflectometer, the load shall be removed and the deflection measured again to determine the permanent set.

In those cases where the arbitration bar is used for such cast materials as have an elastic limit, the increment of load used near the transverse elastic limit shall be 250 lb.

It is well known that when the transverse elastic limit is determined-of course by means of a transverse test, the extreme fiber stress at this transverse elastic limit is not the same as that at the tensile elastic limit of the material; and moreover, that it varies with both the section and the span; hence the desirability of comparing the transverse elastic limit with the tensile elastic limit.

7. In the case of ductile materials, the arrangement of the supports shall be such that longitudinal tension in the specimen due to the rigidity of the supports is avoided.

8. In the case of ductile materials, special care shall be used when determining the ultimate load. For this purpose it will be necessary when approaching the ultimate (that is, the maximum) load, to make the speed of testing slow enough to enable the observer to note the maximum load.

In many cases, as in I and T-beams, the maximum load can be easily ascertained, while in others, such as round or flat sections with short spans, it may not be possible to determine it exactly; but it will almost always be possible to determine it with sufficient accuracy for all practical purposes.

IV. METHODS FOR BRINELL HARDNESS TESTS.

CHEMICAL COMPOSITION AND HEAT TREATMENT OF BALLS.

1. The chemical composition, as far as carbon and chromium are concerned, should be from 1 to 1.2 per cent of carbon, and from 1 to 1.5 per cent of chromium.

2. The heat treatment should be such as will result in making the balls as hard as possible, consistent with the ability to resist the pressure without cracking or crushing.

While a long series of careful experiments would be needed to justify the specifications of more exact conditions in these regards, and while some users of these tests think that the chemical composition (within limits) plays a very small part, if any, in the problem, it is believed that the above requirements will be found satisfactory for commercial work, until such time as suitable experiments shall have furnished the data necessary for making the conditions more precise.

DIAMETER AND FORM OF BALLS.

3. The standard diameter of balls should be 10 mm. with a permissible variation of 0.0025 mm. (0.0001 in.) plus or minus; no ball either new or old showing a greater variation is to be employed. The standard diameter should always be employed, except in very rare cases when some other is absolutely necessary. If, at any time in testing, a hardness of No. 600 be exceeded, the balls should be remicrometered.

Thus far there is not sufficient evidence to show that the hardness numbers will be the same when different diameters of balls are used, and some of the evidence indicates that the reverse is the case; hence the importance of adhering to one size of ball.

PRESSURE.

4. The standard pressures used should be 3000 kg. for steel, and 500 kg. for softer metals. Departure from these pressures should never be tolerated, except in rare cases where it is unavoidable. The time of pressure should be at least 30 seconds

The fact that, with our present light on the subject, we can only regard the results as comparative, renders it important to employ as few different pressures as possible.

MEASUREMENT OF DIAMETER OR DEPTH OF INDENTATION.

5. Whether the diameter or the depth of the indentation is measured, apparatus should be used that will give results as

accurately as a microscope mounted on, and moved by, a micrometer screw.

As to the choice between the two, there exists a very decided difference of opinion, some thinking one and some the other more conducive to accuracy. The source of error in either case (assuming the measuring apparatus to be accurate) is the depression or the elevation of the metal immediately surrounding the indentation.

STANDARD DEFINITIONS AND RULES
GOVERNING THE
PREPARATION OF MICROGRAPHS OF METALS AND ALLOYS.

Serial Designation: E 2 – 20.

These definitions and rules are issued under the fixed designation E 2; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1917; Adopted in Amended Form, 1920.

I. STANDARD MAGNIFICATIONS.

General Use.

1. The standard magnifications for general use in making micrographs, expressed in diameters, shall be as follows:

10, 25, 50, 75, 100, 200, 500, 1000.

2. For general use in Society reports, and for showing grain size, the following magnifications are recommended:

Material.	Cast.	Wrought.
Steel and Ferrous Materials	100	100
Copper	50 and 100	75
Copper-Zinc Alloys	50 " 100	75
Copper-Nickel Alloys	50 " 100	200
Copper-Nickel-Zinc Alloys	50 " 100	200
Lead-Tin-Antimony Alloys[1]	50 " 200	....

Reproduction of Micrographs.

3. (*a*) Reproductions of micrographs in publications shall be made of exact standard magnifications except in those special cases where the details of structure are to be illustrated.

(*b*) If micrographs submitted for publication are not of standard magnification, they shall be enlarged or reduced to the nearest standard size. The actual magnification appearing in print shall be stated under the micrograph. See Paragraph (*d*).

(*c*) To facilitate the reproduction, authors should be advised that their micrographs should be of proper size to fit the printed page, and in order to conserve space that micrographs be printed in the form of squares.

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[1] Including those containing small percentages of copper.

(*d*) With each micrograph shall be printed an explanatory title, together with actual magnification, etching medium, treatment, etc., indicating what the author intends to show, so that it will not be necessary to search the text for general information. With micrographs at magnifications of approximately 500 diameters and above, the numerical aperature of the objective and the type of illuminator shall be given.

(*e*) Photographs in which the magnification is less than 10 diameters are usually made with photographic lenses or single magnifiers. These will be considered as "macrographs."

With each macrograph should be printed an explanatory title, together with the actual magnifications, method of illumination, and general treatment indicating what the author desires to illustrate, so that it will not be necessary to refer to the text for general information.

II. LENSES.

Lenses. 4. For obtaining the magnifications recommended, the following types of lenses are suggested as suitable for general commercial work: 30. (A.I.S.).

(*a*) For magnifications from 20 to ~~50~~: A photographic lense of approximately 35-mm. focal length, to be used without ocular.

(*b*) For magnifications from 30 to 75: A 32-mm. objective with Huyghens ocular (approximately ×5).

(*c*) For magnifications from 75 to 150: A 16-mm. objective with Huyghens ocular (approximately ×5).

(*d*) For magnifications from 250 to 500: A 4-mm. objective (preferably apochromatic) with projection ocular.

Directions. 5. (*a*) All objectives should be corrected for use without cover glasses.

(*b*) In using one of the lens combinations given above, the length of the camera bellows may be adjusted to give the exact magnification desired.

It should be borne in mind, however, that increasing the magnification by increasing the length of the camera bellows adds nothing to the detail of the micrograph. This depends mainly upon the resolving power of the objective used.

(*c*) The magnification shall be determined by accurately measuring the image of a stage micrometer scale, and not by estimation from lens combinations, or microscope or camera adjustments.

III. GRAIN SIZE.

Definition of Grain.

6. (*a*) *Alloys Consisting of but One Type of Crystals* (*e. g.*, copper, alpha brass, etc.): In counting individual grains the original crystal, including the twinned layers, shall be called one grain.

(*b*) *Alloys Consisting of Two Metallographic Components* (*e. g.*, steels, Muntz metal, etc.): The original grain which has given rise to the aggregation of the two components shall be taken as the unit when determinable and the individual component in other cases.[1] When grain size is included in actual specifications, the term should always be defined in such specifications.

Method of Measurement of Grain Size.

7. For measuring grain size, two methods are recommended depending upon the condition of the material:

(*a*) *For Material in which the Grains are Equi-axed* (*e. g.*, most metals in the cast and in the annealed state): The planimetric method as modified by Jeffries[2] is recommended for use as being very accurate and rapid. It is recommended that the circular area used should always include at least 50 grains.

(*b*) *When the Grains are not Equi-axed* (*e. g.*, in strained materials): Heyn's intercept method should be used, the average grain size being determined by counting the number of grains at a given magnification along a line of known length on two axes at right angles to each other, one axis being parallel to the direction of rolling. In some cases a third count along a line perpendicular to the other two may be desirable. This will necessitate the preparation of another polished surface.

Numerical Expression of Grain Size.

8. The grain size as determined by the planimetric method, Section 7 (*a*), should be expressed as the number of grains per unit area (square inch or square centimeter). This may also, but less preferably so, be expressed as the average grain area; or the average linear dimension of the grain may be given. The grain size as determined by the intercept method, Section 7 (*b*), should be expressed by giving the average number of grains per linear unit in the two directions; or the average number per unit area together with the ratio of length to breadth of grain (L/B) may be given.

Use of Grain Size in Specifications.

9. If grain size is to be included in specifications, it should be expressed as the maximum or minimum allowable as deter-

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[1] See U. S. Navy Specifications, 49-S-2-c, p. 7.

[2] See Note on pp. 856–857.

mined above. It is recommended that only in extreme cases should grain size be made the sole basis of rejection of material.

NOTE

JEFFRIES' METHOD FOR GRAIN-SIZE MEASUREMENTS.[1]

A circle 79.8 mm. in diameter is drawn on the rough side of a ground-glass screen, the center of the circle being near the center of the rectangular section of the screen. This ground glass is mounted in a frame which fits a metallographic camera, the smooth side of the glass being on the outside. When the image of the specimen for grain-size determination is focused on the screen, the circle will be plainly visible and its circumference should be well within the image.

When the image is properly focused the grains intersected by the circumference of the circle are checked and counted. Since the check marks must be made on the smooth side of the glass, a soft red pencil, such as is used in laboratories for marking beakers and flasks, will be found satisfactory. The marks used to indicate the boundary grains are usually short, straight lines intersecting the circumference of the circle and perpendicular to it. The completely included grains are next checked and counted, after which the red marks are erased from the glass with a dry cloth. The specimen can then be moved and other measurements made as desired.

TABLE I.

Magnification Used (= *m*).	Diameter of Circle, mm.	Multiplier to Obtain Grains per Square Millimeter (= *f*).
Full size	79.8	0.0002
10	"	0.02
25	"	0.125
50	"	0.5
75[a]	"	1.125
100	"	2.0
150	"	4.5
200	"	8.0
250	"	12.5
300	"	18.0
500	"	50.0
750	"	112.5
1000	"	200.0
1500	"	450.0
2000	"	800.0

[a] At 75 diameters, if a circle 84.5 mm. in diameter, or a rectangle having an area of 5625 sq. mm. is used, the factor *f* becomes unity.

One-half the number of grains intersected by the circumference of the circle, added to the number of completely included grains, gives the number of equivalent whole grains within the circle. If the equivalent number of whole grains within the circle measured at a certain magnification be multiplied by the number in the third column of Table I opposite the magnification used, the product will be the number of grains per square millimeter.

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[1] This method has been condensed from the paper by Mr. Zay Jeffries appearing in *Metallurgical and Chemical Engineering*, Vol. XVIII, p. 185 (1918).

A circle 79.8 mm. diameter has an area of 5000 sq. mm. If it is desired to use a rectangle of the same area in place of a circle for the determination, convenient sizes are given as follows:

70.7	by	70.7	mm.
65	"	77	"
60	"	83.3	"
55	"	91	"
50	"	100	"

Since each of these rectangles has an area of about 5000 sq. mm., the multipliers given in Table I can be used for any one of them, or any other rectangle having an area of 5000 sq. mm. To make a grain-size determination with a rectangular in place of a circular area, the grains intersected by the periphery of the rectangle should be counted, one-half the number added to the completely included grains and the result will be the number of equivalent whole grains within the rectangle. If the determination is made at one of the magnifications given in Table I, the number of grains per square millimeter can be obtained by multiplying the equivalent number of whole grains within the area by the multiplier (f) opposite the magnification used. The rectangle could be used on a ground glass as described above for the circle, or it could be used on a micrograph.

Some metallographists prefer to refer to the grain size in terms of the diameter of the average grain in millimeters, or the area of the average grain in μ^2. The following simple formulas will be found helpful in these cases:

w = number of boundary grains;
z = number of completely included grains;
x = equivalent number of whole grains in 5000 sq. mm. (circle 79.8 mm. in diameter or rectangle having area of 5000 sq. mm.);
m = magnification used;
f = multiplier to obtain number of grains per square millimeter;
n = number of grains per square millimeter;
d = diameter of average grain in millimeters·
a = area of average grain in μ^2.

$$x = \tfrac{1}{2} w + z$$

$$f = \frac{m^2}{5000}$$

$$n = fx$$

$$d = \frac{1}{\sqrt{n}}$$

$$a = \frac{1{,}000{,}000}{n}$$

After considering various criticisms, owing to the fact that 75 diameters has become an established practice for use in illustrating the structure and grain size of wrought copper and the copper-zinc alloys, and that a large volume of work has been done using this magnification, it seems advisable to retain a magnification of 75 diameters for this class of material.

EXECUTIVE COMMITTEE

1921

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REGULATIONS GOVERNING STANDING COMMITTEES.

Adopted, 1910; Latest Revision, 1918.

Note.—By action of the Executive Committee on January 6, 1912, the responsibility for the general Regulations Governing Standing Committees is vested in the Executive Committee and Committee E-5 on Standing Committees, with the understanding (1) that a proposed change in these Regulations originating with Committee E-5 shall be subject to approval by the Executive Committee of the Society; (2) that the Executive Committee of the Society shall make no changes in these Regulations without first referring the same to Committee E-5; and (3) that proposed changes in these Regulations thus adopted shall be announced in the next circular to members and become effective from the date of issue of that circular.

I. ORGANIZATION OF STANDING COMMITTEES.

1. **Creation.**—The creation of a standing committee shall be subject to the authorization of the Executive Committee, acting either on a recommendation adopted by majority vote at an annual meeting of the Society, or on its own initiative.

2. **Appointments.**—Appointments on standing committees shall be made by the Executive Committee subject to the following provisions:

(*a*) On committees dealing with subjects having a commercial bearing, either an equal numeric balance shall be maintained between the representatives of producing and non-producing interests; or the latter may be allowed to predominate by majority vote of the former.

(*b*) The classification of the members of a committee into producers and non-producers shall be left to each committee, subject to the following provisions, and with the understanding that a member dissatisfied with this classification has the right of appeal to the Executive Committee:

(1) A member who stands in the relation of producer to any product within the province of the committee shall be classed as a producer, although at the request of the officers of the committee concerned, attention shall be called to the status of such members in a footnote worded as follows:

These members of Committee..........., classed as PRODUCERS, stand in the relation of PRODUCERS to certain products, and in that of NON-PRODUCERS to other products within the province of the committee.

(2) A nominally unattached expert, who is permanently retained by producing interests in the field of activities of the committee with which he is connected, shall be classed as a producer. The qualification "permanently retained" is to be understood to mean that the expert receives a regular monthly or yearly retainer from one or more producing interests under an indefinitely continuing arrangement.

(*c*) As a general policy, only one individual connected with a given firm, company, corporation, laboratory, or other institution shall be eligible to membership on a given committee, although exceptions to this rule may be permitted at the discretion of the committee concerned. In case two or more members of a committee are connected with the same firm, company, corporation, laboratory, or other institution, they shall, when a division is demanded, jointly command only a single vote.

(*d*) Additional appointments on existing committees shall be made only on the recommendation of, or with the approval of, such committees.

(*e*) Only members of the Society shall be eligible, in general, to appointment on committees, although exceptions may be authorized by the Executive Committee in favor of representatives of government branches or other societies.

3. **Preliminary Organization.**—The President of the Society will appoint the chairman *pro tem.* of a new committee from the representatives of the non-producing interests. The chairman *pro tem.*, after communicating with the other members of the committee, will fix the place and time of the first meeting. He may, at his discretion, appoint one or more members of the committee to prepare matter in advance for consideration at that meeting or he may prepare such matter himself. This procedure is recommended as calculated to economize time at the meeting and to afford a definite basis for discussion.

4. **Permanent Organization.**—At the first meeting of a committee a permanent organization shall be effected by the elec-

tion of a permanent chairman from among the representatives of non-producing interests, and such other officers and sub-committees as the committee may desire. The duties and powers assigned to these officers and sub-committees, and the details of management and administration in general, shall be at the discretion of each committee, subject to the limitations of these regulations.

II. DIRECTIONS FOR CONDUCT OF BUSINESS.

5. **Meetings.**—The meetings of standing committees and sub-committees shall be open only to their own members and to such visitors whose proposed invitation has been approved by the chairman.

6. **Proxies.**—A member of a standing committee shall be authorized to delegate any desired individual as his proxy with voting power, or without voting power, if so specified; but no individual shall have more than one vote at a meeting of a committee.

7. **Election of Officers.**—Every standing committee shall hold an election of officers at or before the annual meeting of the Society occurring in the even years. The term of office of every officer shall be two years and officers shall be eligible for re-election.

8. **Resignations.**—Proposed resignations from office or from membership on a standing committee shall be reported directly to the chairman or the secretary of the committee concerned, and the result of any action taken in such matters shall be reported to the Secretary-Treasurer of the Society.

9. **Sub-Committees.**—Sub-committees shall have no standing in the Society except through their parent committees. Sub-committees on proposed complete standard specifications for materials shall consist of not fewer than six members, and at least one-half of the membership shall be composed of non-producers. Departures from this requirement for exceptional reasons may be authorized by the Executive Committee.

III. REPORTS OF STANDING COMMITTEES.

10. **Reports.**—The reports of standing committees shall be presented at the annual meetings. The report of every sub-committee shall be made to the parent committee and not to the Society direct. If such a report is embodied wholly or in part in the report of the parent committee to the Society, the latter shall make definite references to such features in its own report and recommendations, if any, based thereon.

The report of a standing committee, before its presentation at the annual meeting, shall first have been submitted to letter ballot of the committee and shall have received the approval of the majority of those voting.

A statement of the following form shall appear at the close of every committee report:

> This report has been submitted to letter ballot of the committee which consists of .... members, of whom....... have voted affirmatively, ...negatively, and...... have refrained from voting.

Dissenting members shall have the right to present minority reports individually or jointly.

IV. STANDARDS AND RECOMMENDED PRACTICE.

11. Standards.—"The term 'Standards' shall be applied collectively to (*a*) standard specifications, (*b*) standard tests, (*c*) standard methods, and (*d*) standard definitions."[1]

(*a*) The term "Standard Specifications" shall be applied to specifications designed to govern the purchase of materials. Such specifications may or may not include reference to tests, but they shall include limits for physical, chemical or other properties.

(*b*) The term "Standard Tests" shall be applied to prescribed directions for tests of specific materials, but shall not include limits for physical, chemical or other properties.

(*c*) The term "Standard Methods" shall be applied to prescribed methods of procedure in the conduct of physical, chemical or other tests.

(*d*) The term "Standard Definitions" is self-explanatory.

12. Tentative Standards.—The term "Tentative Standards" shall be applied to proposed standards which are published in the Proceedings for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action towards their adoption as standard.

13. Recommended Practice.—"The term 'Recommended Practice' shall be applied to processes and methods not ordinarily subject to contract between purchaser and manufacturer."[1]

14. Matters of Engineering Design.—In the preparation of proposed standards the consideration of matters of engineering design or construction shall not in general be regarded as falling within the province of the Society. If, however, it should appear to a given committee that the consideration of such matters is, for special reasons, indispensable in specifications designed to cover the customary relations between the producers and consumers of a given product, then reference to such matter in proposed specifications for that product shall be permitted within the scope necessary for the particular purpose above stated. Proposed standards embodying features of the character in question shall be submitted by the committee concerned to the Executive Committee for consideration and comment not later than the quarterly meeting immediately preceding the annual meeting at which the proposed standards are to be presented.

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[1] Quoted from By-laws, Article VI, Section 1

15. Preparation of Standards.—Proposed new standards or proposed amendments of existing standards shall originate in the particular committee within whose province such standards properly belong. No action affecting standards shall be taken by any standing committee except at meetings called for that purpose. Action at such meetings shall be subject to majority vote of those voting, and subsequently to majority vote of those voting on letter ballot of the entire committee. The results of each letter ballot as to the number of affirmative votes, the number of negative votes, and the number of members not voting, shall be announced in the report of the committee to the Society. Dissenting members shall have the right to present minority reports, individually or jointly, at the annual meeting of the Society at which the majority report is presented.

16. Advance Distribution of Standards. — The annual reports of the standing committees shall be transmitted to the Secretary-Treasurer of the Society as early in the calendar year as possible and not less than eight weeks in advance of the date of the annual meeting. Preprints of these reports shall be mailed by the Secretary-Treasurer to every member of the Society at the earliest possible subsequent date and not less than four weeks before the annual meeting, so that members may come to the meeting prepared to discuss such reports and that members not intending to be present at the meeting may contribute discussions by letter.

17. Procedure Governing the Adoption of Standards.—Any recommendations affecting standards presented by the appropriate committees at the annual meeting of the Society shall be subject to the following provisions in Article VI, Section 1, of the by-laws:

"Proposed new standards shall be presented at an annual meeting, at which they may be amended by a two-third votes of those voting. On two-thirds vote of those voting, they shall be printed, as presented or as amended, in the Proceedings and separately under the title "Tentative Standards," on which written discussions addressed to the appropriate committee shall be invited. At the next annual meeting tentative standards shall be subject to amendment by a two-thirds vote of those voting. They may then be referred, by a like vote, to letter ballot of the Society, in which case a two-thirds vote of those voting shall be required for adoption; or, on the recommendation of the committee concerned, they may be continued as tentative, as printed or as amended, in which case the above prescribed procedures shall apply at any succeeding annual meeting.

"Proposed amendments of existing standards shall be presented at an annual meeting, at which they may be amended by a two-thirds vote of those voting. On two-thirds vote of those voting they shall be printed, as presented or as amended, in the Proceedings as part of the report of the appropriate committee; and collectively under the same cover with the Tentative Standards for that year. At any succeeding annual meeting they shall be subject to amendment by a two-thirds vote of those voting; and at the annual meeting in the year in which the book of A.S.T.M. Standards will next be published, they shall be subject to reference by a like vote to letter ballot of the Society, in which case a two-thirds vote of those voting shall be required for adoption.

"The above requirement by which final action on proposed new standards or proposed amendments of existing standards shall be deferred for one or more years may, for exceptional reasons, be waived by a nine-tenths vote of those voting at the annual meeting at which they are first presented. In that case the above prescribed vote as to amendments, as to reference to letter ballot, and as to adoption shall remain unaffected."

"The above requirements governing action on proposed new standards or proposed amendments of existing standards shall be applicable also to proposed Recommended Practice."

18. Standards Involving Patents.—"Reports, resolutions and recommendations pertaining to or involving the use, or proposed use, in a standard or tentative standard, of any device or process which forms the subject matter of any existing patent, shall first be submitted to the Executive Committee, and shall be submitted to the Society only with the approval of the Executive Committee."[1]

V. COOPERATION WITH COMMITTEES OF OTHER BODIES.

19. Methods of Initiating Cooperation.—A standing committee desiring to cooperate with committees of other bodies on like or cognate subjects, or to bring about the appointment of similar committees by other bodies for purposes of cooperation, shall address a recommendation to that effect to the Executive Committee and, on the approval of the latter, negotiations to the desired end shall be conducted by the Secretary-Treasurer of the Society. Such cooperative relations shall entail no conditions at variance with these regulations, and shall impose no restrictions upon the free and independent action of the standing committee.

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[1] Quoted from By-laws, Article VI, Section 2.

20. Regulations Governing Cooperative Relations.

The preparation of Regulations Governing Cooperative Relations is under consideration by the Executive Committee, in pursuance of the following resolution passed at the annual meeting of the Society in 1917:

> *"That the Executive Committee be requested to give consideration to the general subject of the formation of and methods of procedure to be followed by joint committees and the publication of joint reports; whether these joint committees be made up from various committees of this Society or of representatives of this Society and other societies and organizations."*

In its annual reports to the Society since this resolution was adopted, the Executive Committee has pointed out that while the Society continues to cooperate with other organizations through the formation of joint committees under suitable regulations, the whole question of cooperative work between societies has been in such a state of flux during the past two or three years that it has been deemed unwise to endeavor to supply the subject matter of Section 20 of these Regulations.

Accordingly this section is temporarily left blank in anticipation of supplying its contents later.

VI. PUBLICATIONS.

21. Publications.—Committees shall have no right to issue matter for publication through other than the regular Society channels, unless so authorized, for exceptional reasons, by the Executive Committee.

VII. EXPENSES OF STANDING COMMITTEES.

22. Current Expenses.—Expenses for postage incurred in connection with the business of committees will be refunded by the Secretary-Treasurer of the Society on vouchers approved by the chairmen of these committees.

23. Stationery.—Correspondence relating to the business of committees or sub-committees shall be conducted on official stationery which will be furnished by the Secretary-Treasurer of the Society.

24. Extraordinary Expenses.—Expenses for items other than postage will not be assumed by the Society, unless such expenditures were incurred in pursuance of previous authorization of the Executive Committee, on recommendation of the chairman of the committee concerned, and within amounts specifically fixed by the Executive Committee.

25. Special Funds.—Committees engaged on subjects having a commercial bearing shall be authorized to solicit contributions from manufacturers towards research funds. Contributions from consumers to funds for this and other purposes shall be solicited only by the Executive Committee. All funds thus collected shall be transmitted to the Secretary-Treasurer of the Society and deposited by him in bank and placed to the credit of the committees on the books of the Society, subject to disbursement only on vouchers signed by the chairman of the committee concerned.

26. Salaries and Fees.—Committees shall not be authorized to pay salaries or professional fees in any form to any of their officers or members. Assistants in connection with research work may be engaged at salaries or special compensation fixed by the committees concerned, provided that funds for such salaries or compensations shall previously have been deposited with the Secretary-Treasurer of the Society. Payments for such purposes shall be made by the Secretary-Treasurer of the Society only on vouchers approved by the chairman of the committee concerned.

VIII. DISCHARGE OF STANDING COMMITTEES.

27. Discharge of Standing Committees.—Standing committees may be discharged by the Executive Committee, either at their own request or with their consent, on the completion of the work for which they were appointed, or in consequence of protracted inactivity. A standing committee which fails to present a report at three successive annual meetings of the Society will be required to show cause, in a written communication to the Executive Committee, why it should not be discharged.

Standing committees may be discharged for cause by the Executive Committee at its own initiative.

METHODS AND INSTRUMENTS OF TESTING.

The Executive Committee has adopted Regulations Governing Methods and Instruments of Testing, under which Committee E-1 on Methods of Testing has been reorganized. These regulations establish the responsibility of the standing committees for the preparation of methods of testing and the examination, design and recommendation of instruments for testing, as well as the authority of Committee E-1 and the relation between the standing committees and Committee E-1.

NOMENCLATURE AND DEFINITIONS.

The various standing committees have from time to time formulated definitions of terms relating to their respective fields. The preparation of such definitions frequently involves joint action of two or more committees. To facilitate proper cooperation and to give proper recognition to an important phase of the Society's activities, the Executive Committee has organized Committee E-8 on Nomenclature and Definitions. Regulations Governing Nomenclature and Definitions have been adopted establishing the authority of Committee E-8 and providing for cooperative relations between it and the other standing committees of the Society.

AMERICAN REPRESENTATION ON COMMITTEES OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Nominations.—In making nominations for appointment of American members on International committees on a subject, falling within the province of an American standing committee, the sense of the latter committee as to the selection of the nominee shall be obtained before final action on the part of the Executive Committee.

Relation between American Representatives on International Committees and American Committees on the same Subjects.—The American representative or representatives on an International committee dealing with subjects falling within the province of an American standing committee shall keep that committee fully advised as to the important developments in the work of the International committee. Formal recommendations to the International committee on the part of such representative or representatives, and their vote on letter ballot of that committee, shall be subject to advance approval on the part of the American committee.

COOPERATIVE POSSIBILITIES BETWEEN U. S. GOVERNMENT LABORATORIES AND A.S.T.M. STANDING COMMITTEES.

The basis on which various government branches may cooperate with the committees of this Society is indicated on pages 869–871. Any committee desiring to establish such cooperative relations shall address a recommendation to that effect to the Executive Committee, and on approval of the latter, negotiations to the desired end shall be conducted by the Secretary-Treasurer of the Society.

SUPPLEMENTARY REGULATIONS GOVERNING STANDING COMMITTEES.

The standing committees of the Society may adopt supplementary regulations governing their various activities. Such regulations have been adopted by a number of committees of the Society.

BASIS OF COOPERATION BETWEEN VARIOUS GOVERNMENT BRANCHES AND THE STANDING COMMITTEES OF THE SOCIETY.

For the information of the membership at large, and especially the standing committees, the Executive Committee has authorized the following announcements, in alphabetical order, of the conditions under which certain government branches are prepared to cooperate with the work of the standing committees, these announcements having been prepared by, or with the approval of, the directing heads of the government branches concerned. Any committee desiring to establish such cooperative relations shall address a recommendation to that effect to the Executive Committee, and on approval of the latter, negotiations to the desired end shall be conducted by the Secretary-Treasurer of the Society.

Bureau of Chemistry.—This Bureau is equipped to do all kinds of chemical work and to participate in cooperative work whenever it can be done within the scope of the functions of the Bureau and under the law, inasmuch as the activities of the Bureau are specifically prescribed by acts of Congress. This cooperative feature would include the investigations under way and such as might be undertaken in connection with the work of the Bureau along the lines of its natural growth and development.

In so far as the Bureau has equipment suitable to carry on investigations and cooperative work on such subjects as are related to chemistry, and with which the American Society for Testing Materials is directly concerned, and where the proper authorization exists and funds are available or the purpose, it would be glad to be of assistance to the committees of the Society.

Bureau of Mines.—The Bureau of Mines may make tests of fuels, explosives and certain mining appliances, such as lamps, timbering, etc. When such work is performed other than for the Government of the United States or state governments, a reasonable fee to cover the necessary expenses is charged.

The Bureau is prepared to cooperate, and will welcome opportunities for cooperation, with committees of the American Society for Testing Materials to the extent of being represented on such committees as are concerned in tests or investigations of fuels, explosives or miners' lamps, and will conduct investigations or tests concerning any phase of these which may be brought to its attention by your committees as needing solution, providing it concerns subjects in which the Bureau is interested on behalf of increasing safety in mining or use of fuels purchased for or belonging to the United States.

Bureau of Public Roads.—The Bureau of Public Roads will cooperate with the American Society for Testing Materials along all lines of laboratory or field work relating to road materials. The Bureau has all the necessary equipment for making such tests. The Bureau can also cooperate along any reasonable lines of field investigations.

Bureau of Standards.—The Bureau of Standards is equipped to conduct investigations covering the standardization of weights and measures, electrical measurements, the determinations of heat constants and temperature measurements, optical properties of materials, chemical problems, investigations of structural and engineering materials, and metallurgical investigations. In addition to general research investigations, it studies problems which arise in the preparation of specifications or the development of methods of testing required in the determination of the qualities of materials. Much of the work is closely allied to the work of the standing committees of the American Society for Testing Materials, and it is the desire of the Bureau to cooperate in those investigations where the Bureau is equipped for them. Investigations may be referred to the Bureau which fall within the authorized scope of its functions, and will be taken up as far as equipment and funds will permit.

Forest Products Laboratory.—It is the aim of the Forest Products Laboratory to promote economy and efficiency in the utilization of wood and in the processes by which forest materials are converted into commercial products. Investigations at the laboratory are being made along the following lines:

Mechanical and physical properties of woods and derived products.
Principles of seasoning and kiln drying.
Decay, preservative treatment, and fireproofing of wood.
Manufacture of pulp and paper.

Distillation and chemical constituents of forest products.
Specifications and grading rules for forest products.
Efficient design or composition of articles obtained or manufactured from forest products.
Design of apparatus, specifications for material, and improving of processes to promote a more efficient and closer utilization of forest products.
Testing and designing of shipping containers.

In order to further the application of the work of the laboratory it is necessary to correlate the results of all technical investigations with the uses of the products and to make all information available to the public.

The laboratory, in all matters within its scope, will be glad to cooperate with the American Society for Testing Materials so far as funds and equipment are available.

Watertown Arsenal.—The laboratory of the Watertown Arsenal is equipped for conducting physical tests of metals and materials, including impact and repeated stress tests; metallographic examinations of metals, chemical analysis, pyrometric work and investigations on the manufacture and heat treatment of steels. The testing laboratory is limited by law to investigate tests and tests of material in connection with the manufacturing work of the Ordnance Department, except as modified by authority to make tests of materials for private parties paying the cost of the test. Within these limits the Watertown Arsenal will be glad to cooperate with the standing committees of the American Society for Testing Materials.

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OF THE

STANDARDS.

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